GERMS OF MIND IN PLANTS

By. R. H. FRANCÉ

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Translated by A. M. SIMONS

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TRANSLATOR'S PREFACE

Since my boyhood days, when the great forest was my playground, I have ever been a lover of nature. Because I hoped this little book might bring a portion of this pleasure to some, who, like myself, are largely shut out from direct contact with field and forest I have turned this work into English.

There is another reason why I have done this. Science must, in the future, be made the property of all. Its structure needs the assistance of many willing hands if it is to reach that rounded perfection which is a part of any true science. This does not mean alone that the technical language of specialists should be simplified. It means far more the participation of the great mass of the people in the discovery and elaboration of scientific truths. The specialist and the philosopher must co-operate with a host of observers if the vast multitude of facts which are necessary to determine great natural laws are to be gathered and systematized.

This same science is an instrument by which the workers can secure their emancipation from the industrial slavery amid which they now live. The essentially revolutionary character of modern science is recognized by the ruling class to-day, and but little effort is therefore made to bring these truths within the reach of those whom they would help to freedom.

Because personally I love nature, because the truths of science bring strong support to the movement for industrial and social freedom, and because science can develop to its full measure only in a world where the workers are free; because, in short, I am both a socialist and a nature lover I have done this little as a contribution to the cause of socialism and science.

A. M. SIMONS.

GERMS OF MIND IN PLANTS

If Paradise means a portion of the earth, as yet unpolluted by the presence of man, then it must certainly be a Paradise of nature-lovers. In the marshes of the lower Danube there are still whole square miles as untouched as if man had not yet begun his conquest of this globe. As far as the eye can reach, a wilderness of reeds, sprinkled with thickets of willow and alder, penetrated with tiny brooklets, whose golden brown or dark green waters lead to hidden laughing lakes, where water lilies bloom and a thousand strange flowers nod, and great herons gather in ancient eyries; where pelicans sit upon the trees, and countless water-fowls conduct a deafening concert,— where, also, millions of blood-thirsty insects stand guard over this Para-

dise to prevent intrusion. An old fisher and buffalo herder guided me there in a boat such as is no longer to be seen in Europe. He was a curious old fellow. These swamps had been his life-long home, and he knew them and their world better than any naturalist, since for fifty years he had done nothing else but observe nature,— fishing, philosophizing and watching his buffaloes. On their broad mud-bedecked shoulders he could go, as if upon a swimming island, through the most dangerous morasses, which would have been impenetrable to a boat. Such men are as silent as nature herself. But when they speak it is to say something worth while. With distrustful silence he looked upon the strange guest of his primitive world, who now pulled up plants, then fished with his net, and between times wrote mysteriously in a little book. But during the noon-day rest he thawed out somewhat. I sought to draw him into conversation, but elicited only monosyllables. Finally after a searching look—

"What use do you make, my dear nephew" (it is a beautiful trait of these men of nature to address every one as a relative), "of all those weeds? They are no good," he concluded very scornfully.

This gave me the opportunity to open a conversation. "Now, Uncle Mihály," I said, "do you really have any use for the young of the grey heron? Yet you went to-day to see if they had already hatched. Why? Because you enjoyed doing it. In the same way I come to you, because I like to have the flowers, and you know well, there are flowers here that are to be found nowhere else in the world."

The appeal to local patriotism brought rich reward. With a nod the old grumbler murmured.

"Do you know all the flowers?" he asked.

"I came here in order to learn them."

Renewed silence. But he looked at me, now with satisfied condescension, then again with a certain reluctance.

"I know something that perhaps the gentlemen in the cities do not know."

"Now, Uncle Mihály, what is that?"

"I do not know whether you will believe me. There is a plant on that island that covers itself up at night. That is no fairy story, I have seen it myself."

When I agreed with him, and told him much more of the sleep of flowers and vegetables, then he began to treat me as an equal, and from then

on he disclosed to me a wealth of marvels, and a deep knowledge of the life of nature, such as can be attained only by long and close communion with her.

Ten years have passed away since then and "Uncle Mihály" dwells already in the real primeval world of things, for which, however, he never longed, because, as he naïvely and shrewdly remarked, perhaps a man can not fish there. But when I think of his departed shade, I am impressed with how great a source of true wisdom we have neglected in giving so little attention to such men in our culture, and how we have thereby excluded the whole great mass of popular wisdom from our science. I often think that these children of nature know nearly everything that is really worth knowing about nature. To-day this wisdom is hidden, disguised in tales, superstitions, and proverbs, or else dies unspoken, because no one asks for it.

Fables and tales have come ringing down from primitive times, whose fantasies are incomprehensible to us. But what if all men were so "nature wise" as "Uncle Mihály," thoroughly trained through manifold observations of the world and its wonders? Such men have not failed to leave a trace behind them, for tales,

folk-songs and religious images are their legacy to us. Therefore it is of deep significance that in all popular sayings, the plants are living, perceiving, acting creatures. This popular idea finds poetical expression in the Dryads, those nymphs of tree and forest of the ancient Greeks, who with a tree were born and with it died.

The narcissus, hyacinth, laurel, and cypress retain their human fate and stand as enchanted mortals, in the sunny southern forest of the gods. For the Germans also, forest and meadow are filled with living if silent brothers, and their gentle queen, Balder's wife Nanna, comes down to us every year in the gorgeous pomp of fairyland. In India this dim outline becomes a philosophy, in which all nature meets us as a mirror saying: "This is you." Wherever we dig down into these old sources we meet with the same stream: the deepest conviction of a bygone race, whether it be in the wonderful didactic poem of Empedocles:

> "For I was once perhaps as boy or girl
> Dust, mayhap, or bird and fish" . . . .

that in playful mixture of poetry and fundamental wisdom speaks that mystic phrase: evolution long ago began the unveiling of man;

whether it be in the mystic sayings of the Middle Ages, of the wonderful herbs that talked on Christmas eve, or of the mandrake that gave a heart-breaking cry when pulled from the earth.

In the folk-songs of the Russians and Norwegians, the plants are living, feeling fellow-creatures, and even with us, in spite of our long separation from nature, there still remains a remnant of the old feeling, that the plants are animate creatures, which our poets, at least, will not permit us to forget.

We have become separated from nature. This sentence may appear to many somewhat startling and yet it is certainly true. The long and uninteresting story of this separation began with Aristotle and ended with blind faith in literalism and the illusion of authority. The chance statement of Aristotle in his book on animals, that the plants have souls but no sensation, was accepted as inspired by the unfortunate trend of thought in the Middle Ages, which ceased to believe in the evidence of the eyes, when it differed from the written word, until Linnæus, who stood wholly upon the shoulders of the Middle Ages, raised it to the position of a dogma. This man, who had such a mania for registration that he classified even his friends into categories and

subdivisions, maintained, through his great authority, even into our youth, a dead scheme of life drawn out of scholasticism, that has gained him the name of the *Verus botanicus,* the true botanist. Wherever he went the laughing brook died, the glory of the flowers withered, the grace and joy of our meadows was transformed into withered corpses, which this "true botanist" collected into the folios of his herbarium, and whose crushed and discolored bodies he described in a thousand minute Latin terms. This was called scientific botany, and the more mummies such a register of the dead could bury in his museum the greater botanist he was held to be. This "true botany," however, was still the teacher of our teachers. The learning of these endless descriptions was one of the terrors of our school life. The blooming meadows and the storied woods disappeared during the botanical hour into a dusty herbarium, into a dreary catalogue of Greek and Latin labels. It became the hour for the practice of a tiresome dialectic, filled with discussions about the number of stamens, the shape of leaves, about over-amidst—and underplaced bunches of fruits, all of which we learned only to forget.

When this was completed, we stood disen-

chanted and estranged from nature. So it came about that in the broadest circles of culture, the secret but universal judgment was, that botany was unspeakably dry, a pedantic cram, a sort of intellectual gymnastics. Respect for the teacher prevented us from saying this openly, but if one was a true lover of natural science, botanical books were generally the last for which he reached.

This meant the renunciation of one of the greatest of pleasures. The most beautiful part of nature was thereby, lost. But during the last decade something wholly different from that which the good old Linnæus treasured is appearing in botanical works, and this "true botany" is already dying out. It is at last beginning to be realized that the forms of plants are but skeletons, beautiful to be sure, pleasing and of manifold, playful forms, but which after all are only the covering of the true kernel,— the life of the plant. This last, however, is filled with hitherto unseen, unobserved marvels of nature.

How did we arrive at this knowledge? In order to understand this we must turn back once more to these "catalogues." The botanists had almost completed the inventory of nature. It cost many a tiresome quarrel, and often dan-

gerous expeditions, to find "new" and undescribed species. But this did not frighten them. It is a strange leaf in human history, on which is written the story of these tireless undaunted wandering botanists, who struggled through wastes, climbed unexplored mountains, searched among hostile unknown people, went hungry, thirsty, often perished and endured all this — in the hope of bringing home a dozen hitherto undescribed vegetables. But it is evident that all could not do this. Because there were really so few new herbs to discover, men at last began to look closely at the old ones. So it came about that "true botanists" began to content themselves with a half a dozen specimens. Among the hundreds of herbs that he had pressed at home there was always one that had a hair more or less than the description called for, one of those trifling changes, from which nature develops new forms of life, and soon a host of "joyful discoveries" were made in the herbariums. But such work gave a new insight into life. Form is but the track left by life. As the bodies were dissected, the plants investigated in their natural conditions, and their development observed, new characteristics were constantly discovered which could be used for the differ-

entiation of new divisions, and therefore these were ever more eagerly sought for. These characteristics, however, were expressions of vital laws, and so finally many a botanist, to his great surprise, discovered that the plants, these lifeless and helpless things, that even in death were so striking and attractive, really had a part in the great battle of life, and quietly, modestly, but none the less surely, through slight movements and curves, defended themselves against enemies and misfortune. It was discovered that they lived in an oft dramatic battle, that they were tireless in the display of new expedients, in artifices and adjustments, to obtain everywhere the first triumph of life over "dead matter," each in its own way with its own individuality; that they had long ago found a way to utilize all the rest of nature, and had created a thousand relations between them and this concealed and yet so powerful life, and had formed connections for reciprocal advantage and support through its creatures, the beetles, flies, bees, butterflies, snails, and birds.

The flower-strewn meadow, every scanty pasture, even the great silent forest, all are a murmuring symphony of the most marvelous and beautiful life-phenomena. It is only the good

botanist who does not hear it, because he has driven the spirits of nature out of his herbarium, and therefore they do not exist.

So it was that in an unexpected manner the old popular wisdom began once more to receive respect. Out of the fables and songs and sayings this kernel of truth came forth: *there is something in the plants like unto that which we find in our own breast.* When this was finally observed there was no end to the astonishment.

Gone was the time of dead descriptions of leaves and blossoms. A new life had entered into botany, and during the last generation it has been something wholly different, a continuation or if you please, the beginning of the knowledge of the true nature of man. For as mankind pressed deeper into the puzzling laws that ruled the forces in tree and blossom he discovered that there was something in everything that lived and worked, which in its infinitely more perfect form in us leads to a conscious direction of life. It is only much more simple in the plants and less affected by external disturbances, and confined within narrow limits, and therefore *more easily understood.* For all those who yearn for the solution of the secret of our existence, an attractive perspective opened up, the

hope that if anywhere the question of life had become so simple that we could understand it, it must be in the plants.

But of all this vision into the first forms of "human existence" our scientists knew almost nothing, and they could know almost nothing. The knowledge was not embalmed and concealed in those last heritages of the Middle Ages, which the "true botanist" had left to us, couched in a technical language almost unintelligible to the popularly educated man, which in science still served to divide the laity and the initiate. It was scattered through a thousand essays and unintelligibly written books. For while the "florist" no longer ruled in botany his sceptre had descended to the "specialist." He, however, is a necessary evil. Because life takes on such a multitude of forms, it is the despair of the majority of those who would seek to examine the whole. Certainly if we are to follow its laws to the utmost bounds, one life is not sufficient, and therefore each one must confine his work to some little corner of the great structure of science. But however useful and necessary they may be, these special investigators, like the workers in a watch factory, one of whom makes a wheel, the other only a screw and the third only

prepares a spring, always have need of *one* who will gather together the parts of the whole watch. Otherwise the work of the laborers is in vain. Just so science needs men who must seek to know the whole of life in all its relations, in all its expressions, stages and struggles from the metal, whose strange lifelike phenomena are the latest discoveries of the investigators of life, up to the thinking brain that has the incomprehensible gift of comprehending all these life relations. It is above all the popular knowledge and culture which needs such a general view; indeed this is all it can use of the whole system of botany, for the confusing mass of special knowledge is of no value to the popular mind. Therefore, we may be excused if we confine ourselves to this division of the study and give a comprehensive view of these characteristics which will give our nature lovers a survey of how the life of plants is actually constituted, and show why it is important for us to know this.

. . . . . .

An exception can be offered to me at this point, and the claim made that no modern botanist denies that plants are living beings. To such we may reply that it practically amounts to the denial of life when plants are refused the possession

of such an important and peculiar attribute of life as sensation. Yet this is just what nearly all the scientists have done until within very recent years, and even now the public and the common educational thought know practically nothing of plant sensation. A being that remains fixed and motionless in a single spot, growing with imperceptible slowness, even slower than the growth of a crystal, a being that responds neither to the most violent attacks or the most friendly attention,— such a thing will never be recognized as living by the everyday world. Even the humblest worm turns when trodden upon — the plants apparently remain entirely still.

Yet this conclusion is due only to a lack of observation and patience. The plant possesses everything that distinguishes a living creature — movement, sensation, the most violent reaction against abuse, and most ardent gratitude for favors — if we will but take sufficient time to wait with loving patience for its sweet and gentle answers to our stormy questions. We do not notice a likeness to our rough, hasty, violent actions, and therefore we conclude that we are of different natures. But with knowledge comes modesty, and if we will but approach these lovable children of nature with indulgent patience,

then leaves, twigs, fruit and flowers, softly, but clearly, whisper to us: "We are of one nature . . . thou also wert once as we." It sounds like a fable, but science always exceeds imagination. What to the ignorant is dull dead matter, with the wise verges on the highest poetry.

I will not speak here of the thousands upon thousands of creatures to be found in the quiet pools, in rushing mountain torrents, and in the depths of the ocean, which scramble about, join in merry dances, creep deliberately around or shoot like an arrow through the water — and yet which scientists call plants. I will not speak of these since they would not ordinarily be recognized as plants — for they are the very beginnings, the primitive germs of life — like the infusoria, with which they are always being confused. They are at the beginnings of organization, where the boundaries of nature are not yet clearly defined. To be sure the line of forms from these one-celled algæ and fungi and bacteria up to the billion-celled oak, is an almost unbroken one. How the first dancing, living globule comes to rest, then unites with another, at first coyly and momentarily, then permanently; how these families of cells stretch out into green water-threads, then roll up into little discs, then

into simple leaves; how they divide their life tasks, how the firmly attached portion sucks up nourishment, while the free portion in the light digests and breathes; how slowly the organs of multiplication evolve, how the transition from water to land life is accomplished,— all this we see as in a wonderful plastic changing picture, and therefore we know, that that trembling globule in the green drop of water is already a tiny plant — but all this requires a book of its own, and therefore I will be silent here.

Neither will I speak of those vital processes that go on inside the blossoms, of the fine streams that pulsate through the plants, and the gentle stirrings and movements, which the secret of fertilization hides for us. But plants also move their whole bodies, as freely, easily and gracefully as the most skillful animal — only much slower. The roots burrow inquiringly into the earth, the buds and twigs swing round their narrow circles, the leaves and blossoms bend and shiver with changes, the tendrils circle questioningly and reach out with ghostly arms for their surroundings,— but the superficial man passes and thinks the plants motionless and lifeless, because he will not take the time to watch them for a single hour. The plants however, have

plenty of time, therefore they do not hurry; for the giants of Flora's realm live through tens of centuries, and see countless generations of men rise and disappear beneath their feet.

It cost time to demonstrate the fact, but now we know for a certainty that *there is no plant without movement.* All growth is nothing but a series of tiny movements, and while life exists within a plant it is constantly occupied with bendings, turnings, and quiverings. To be sure these movements are not so quick as those of our organs, they do not arise from the contraction of muscles or from elasticity, but — well certainly by some means not yet clearly understood. One thing can not be concealed, and that is that in the sense-life of plants we are very close to the beginning of all knowledge. It is as yet an undeveloped country, and every nature lover can here make discoveries and personal observations that will gain him the thanks of science.

The physiologists say that these movements of the plants — nutations they are called — are brought about by variations in the pressure of the liquids in the sap-filled organs, as it flows first to one side and then to the other. This causes the parts to bend. Or else it is because one side sometimes grows faster than the other.

A slight consideration of this statement shows that it is much as if one were to say that a locomotive travels because some one has opened the throttle. Certainly this answers the question as to what started the motion, but still we should really know nothing as to the actual cause of the movements. We would rather say honestly that at present we know only the fact of these hidden movements but not their true cause. At any rate their observation will give us enough to do for some time, so varied are these movements.

One of the most lively of the plant organs is the root, or more correctly speaking, those fine worm-like rootlet ends, whose tips Darwin, not without reason, likened to a brain. The things this little white thread can accomplish are almost incredible. First of all it turns its tip slowly but constantly round in a circle, crowding itself firmly into the soil. Every one who has observed this compares it to a searching for nourishment. By this means the roots taste every morsel of earth in their vicinity. Stranger yet, when the earth is dry the roots turn away toward moister places. Their growth is always toward greater moisture. The physiologists call this hygrotropism — a sense of the nearness of water.

But the roots also turn downward. They have a sensation of gravity (geotropism). It is as if tiny ropes drew every growing thing constantly deeper into the earth. If we examine an old clover field or a moor, where this can be especially well observed, we shall find that each year they have gone about five centimeters deeper into the earth, measured from the point where they first sprouted. This is accomplished only by a constant growth of the subterranean stalk, but it is just this that gives it a firm position. Living beings know how to turn everything to their advantage. That is one sort of natural law which forms the deepest root of human egoism.

But this attraction of earth and water is not the only motive force of the roots. They develop such energy that they can bore through a sheet of paper — a gigantic task for a weak root tip! But what a purposefulness is in this movement! If an obstacle is met it turns aside; if it is such as to injure the root tip, then it grows quickly away from the threatening environment. Under the forest floor there is always a subterranean host of such mysterious living moving "vegetable worms," engaged in nourishing and increasing the life of grove and plain.

An activity equal to that which the roots main-

tain in the darkness is possessed in daylight by the tendrils, those gracefully entwined and many-curled feelers, which with cords of green bind the roaming vines, gourds and melons fast to their support. Any vineyard or garden arbor offers an opportunity for a most interesting natural experiment. It is impossible not to see this if we look closely at a vine climbing up on a trellis. Like a polyp with a thousand tentacles, so tendrils upon tendrils reach searchingly into the air. And whoever will take the trouble to watch for half a day will discover that they are really searching and testing, since their tips are slowly circling around, about once in every sixty-seven minutes. At the same time the tendrils are slowly raising themselves into the air; others follow them, and so it is that on a warm sunny day (and only on such days are these things plain) there are hundreds of polyp-like arms reaching out from the peaceful arbor, trembling and quivering in their eagerness, not for prey, however, but only for a new support for their heavy stalk.

If none be found they sink down — if below also they find no twig, no wall, no trellis on which to cling and climb, then they raise still higher in the air, always remaining on the extreme outposts, the most favorable points from which to

gain new supports. The moment such a support is reached the tendril awakes to new life. At once,— after a delay of perhaps twenty seconds — the already curved end wraps around the object and within an hour it has wound itself so firmly round that it can only be torn away by force. Then it curls itself up like a corkscrew and by this shortening raises the vine up to it, and in this manner vines slowly climb over trees and walls.

But tendrils are not the only things that swing in the sunlight, every sprout and every growing stem describes this quivering circle. This is most beautifully observed in twining stems such as the hop vine, whether it runs along the edge of the forest or creeps up the high poles to rejoice the heart of the farmer with its sweet odor. Look closer at the magnificent garlands it forms. The tip of the stem swings constantly in wide circles around the chosen branch, to which it will finally cling. With a little patience and the aid of a piece of paper on which the location of the tip is marked, we can see its delicate little green cap wander in perfect circles seeking for new supports.

Every flower shares in this activity, every leaf thereby shows its life. My old buffalo herder

had observed correctly; his marvelous vegetable was the *Oxalis,* or sorrel, in which this movement is plain — but thousands of other flowers and leaves are no less remarkable. This is most plainly seen in walking over a pasture or

The Oxalis, in the midst of the forest. The four leaves to the left have taken the night, those on the right the day position.

meadow at twilight or dawn. To be sure we city-dwellers are seldom able to do this, but mountaineers have often remarked that during those hours the hill-sides are bare of flowers. The day before they were thickly strewn with

the white shooting stars and marigolds, and flecked with the sparkling blue and red of the gentian and crow-flower and lit up with the burning yellow of the cinquefoil, but now all have disappeared. Have they sunk into the earth? No; but they are still "sleeping." Old Linnaeus knew this; and was the first to write a thoroughly scientific discussion of it; his *Somnus plantarum* (the sleep of plants). But in spite of this fact he held that plants were not sentient creatures. For the pedant, life itself is dead. To be sure it is only a euphemism, in reality the meadow flowers do not "sleep" — and therefore it is better to call this condition — night influence: (*Nyctitropism*) as do the latest botanies. Most flowers close their petals, indeed many, as for example the blue-bell, the pansy or the carrot hang their flower-heads as if wilted. Consequently the splendor of the flowers disappears at night only to be restored by the morning sun. But all the flowers do not open and close their petals at the same time so that any definite *"flower hour"* can be compiled for the change, which through its regular appearance, will announce the time.

The plants have also proven themselves to be weather-prophets, since on the approach of rain

the meadows change, and sorrowfully close their thousands of flower cups. Whoever climbs up on the high mountains to the snow line where the last flowers are peeping amid the rocks, will find there the experts in sensitiveness. The little Alpine gentian (*gentiana nivalis*) which lures us on with its friendly blue eyes, has so perfected this feature that in cloudy weather, such as is the rule in high altitudes, it opens its blue calyx every few minutes, for each fleeting ray of the sun, and closes them for every passing cloud.

The sleep movements of the leaves are no less striking. Whoever has walked through a clover-field or among the sainfoin in the garden lots in the evening, or around the village where during the day the yellow coronilla-wort attracts thousands of bees, will be rewarded by a peculiar view of all these. They have drawn together as though struck by frost, and nod as though overcome by sleep. Their tiny leaves are pressed close together, sloping outwards. Since sundown they have responded to their night attraction. But why? Many a botanical head has been racked over this peculiar movement.

Bishop Alb. Magnus, who was denounced as a

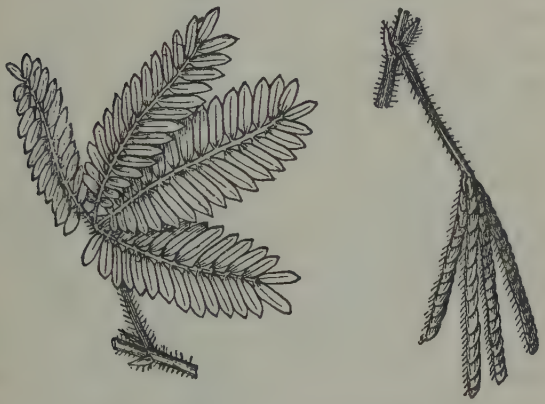
wizard, said over 600 years ago that plants slept the same as men, and this comparison was one of the charges in the complaint against him. The great Darwin gave much study to this phenomenon, and thought that this sleeping position constituted an important protection against cold, especially against frost, but later investigation has gradually led to the conclusion that it is rather to prevent too heavy a deposit of dew, which is injurious to the life processes of the plant. It is, however, worthy of note that it is not the increasing dampness that causes this movement, but simply and only this removal of the light. Any one can prove this. If clover leaves are cut off and plunged in water they will open their little leaves to the sun as wide as possible — but if they are carried into a darkened room they will fold them shyly together and "sleep." These facts make a strange chapter from which much may be read.

Some of the more impatient of my readers must have been long thinking of the proverbial Mimosa, or "sensitive plant," ever since we first began to speak of movements in plants. But I believe that only when we have first studied the sleep of plants can we come to understand properly the movements of the Mimosa. It, with

many of its fellows, "sleeps" whenever it is roughly touched. Every one knows this, but no one knows why. Why is the Mimosa so sensitive and of what use is this quality to the plant? Some scholars say that it serves to shake the rain quickly from its leaves, others that it frightens the animals that would eat its leaves. This latter is a most marvelous suggestion that makes our previous observations seem very commonplace. It sounds somewhat fantastic to speak of plants moving suddenly to frighten away animals.

Let us give the Mimosa a little closer examination. Although familiar to almost every one, there are some things about it that have hitherto been known only to the professional student. This feather-leaved little bush that looks so much like a mournful gentle acacia, reacts vigorously only in the South. In our hot-houses and gardens it is always somewhat dull, like a sorrowing child, and responds less readily to every touch. The feather-like leaves rise, fold together and the stem sinks down. Every one knows this. But every one does not know that even the neighboring leaves of this "dumb weeper" are affected. If the touch was rough or if the first leaf received any injury — if it was cut or burned

for instance, the whole branch is set in activity, and soon the whole bush follows. From leaf to leaf, from stem to stem and finally from branch to branch it proceeds, and everywhere the stems sink down, the leaves fold up, thereby proving



A branch of Mimosa, before and after touching.

something that has never been believed of plants, —that their entire body perceives what happens to a single leaf.

Still less is it commonly known that the Mimosa is no exception. It has been fortunate enough to become proverbial, so that we have all too

easily forgotten that it is only one of many "sensitives" in the flower kingdom. In the depths of tropical forests there is a little oxalis *(Biophytuno)* that is no less sensitive to shocks and touches, and indeed our gentle shade tree the false acacia, called the locust, draws itself together in the same way, only it is much more robust and requires a harder blow to frighten it. Indeed it is now being finally recognized that nearly all leaf stalks, on receiving a violent shock, will bend down at their joints as a sign that they have perceived it.

That its sensitiveness rises with the temperature, need not surprise us, since the classical example of plant activity is to be found only in the forcing temperature of the tropic jungle. On the banks of the Ganges, made sacred in song and story, there grows a marvelous bush, the telegraph plant, of which the Indian poems of Mahâbhârata and Bhagavad-Ghitâ and the tales of the thousand and one nights tell us that it is condemned to forever move its leaves round and round in a circle without rest or respite until it dies. Botany shows that this poetical marvel is an actual marvel. In the speech of Linnaeus the plant is known as *Desmondium gyrans,* and plant physiologists testify with many shakings

The Indian Telegraph Plant (*Desmodium*), that spontaneously moves its little side-leaves.

of the head that this oriental tale, like many another one, is true.

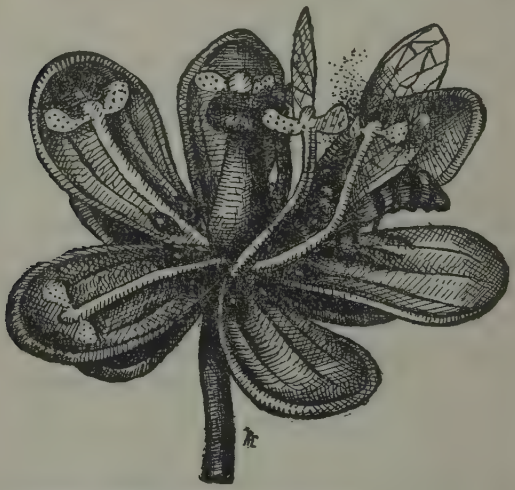
The leaves of the little bush are arranged in a holy trinity, like those of the clover, with a large one in the middle and a smaller one on each side. The latter turn in a restless circle noticeable even to a fleeting glance. They swing up and down about once every minute and a half. This life awakens only with warmth. Even at 21° Centigrade, they are dead and motionless. Why is this activity confined only to warm periods? We do not know. Why does the plant thus fan itself cool? It is a puzzle. Why do only the side leaves swing? No one can tell. Meanwhile we can only look and marvel and point to it as a proof that plants live and move. We only know that its life is most intensive in early youth. In the same way it is only the young pansy and carrot blossoms that close up at night. It is only the young budding *Desmodium* leaves that are in constant movement, swinging restlessly back and forth day and night. Age alone tames and quiets it — just as with us.

Darwin, who was an eager investigator of this phase of plant-life, claims that it is not necessary to go to the sacred land of India in order to see such marvels. The fronds of one of the most

beautiful ferns that deck our woods, the Maiden Hair *(Asplenium trichomanes)* swing on warm sunny days in the same manner as the *Desmodium.* I noticed this statement, and have lain for many a quiet hour watching amid the green wilderness of ferns that covered some southern slope — but nothing moved, save the shadows gently stealing from leaf to leaf. Neither have I been able to find any further confirmation in literature — but Darwin was too truly scientific for us not to believe him. Perhaps on some hotter day some of my readers may have better luck. They can still live a fairy-tale — seeing the spirits of nature moving and living in a German forest. Here we shall find the kernel of truth from those beautiful myths, that are told the whole world over, and which people forest, thicket and rock, with a sometimes drolly teasing, and sometimes maliciously mischievous race of elves.

If scholars had always given heed to the tales of the people, many a discovery might have been made centuries earlier, and since in logical thought the farthest mesh is united with the whole net of ideas — who knows what might have come from such discoveries? In many places the people already know that the blos-

soms of the Barberry bush, which grows thickly on the edges of every forest, conceal a strangely moving life. These little yellow stars are among the first harbingers of spring, and therefore it is with double joy that we study this awakening of plant life.



A slightly enlarged blossom of the Barberry covering a honey-seeking insect with pollen.

I was once compelled to memorize the following sentence concerning the Barberry *(Berberis)* from an old text-book on botany: "Owing to

the position of its flower organs, and the sudden springing up of its six anthers, this bush is very striking." Our people, however, know a more interesting side of it. In the herbarium it is only the anthers that spring up, but in life there are some other things springing around in this plant. Look once at one of these little blossoms during the month of April. In the center there is a little column with a cap, like a miniature pillar. This is the pistil, the cradle of future generations. Around this stand the six stamens which we already know. They are bent down gracefully close to the yellow petals and bear, one on each side, two little pockets filled with pollen. At their base are two little cups. In them glows the dark orange honey, an alluring meal for the bees, who with the first rays of the morning sun, swarm greedily to the plant, attracted by the odors, which it pours forth to be wafted far and near on the early breezes. They rush swiftly to the little spoons full of honey, but scarcely have they touched them when, snap, the anthers spring above the bee like feathers, scattering the pollen over his head. It is a delightful spectacle to reproduce this tiny catastrophe with the point of a needle. The slightest touch suffices to send the stamens up with a snap. There is nothing more

sensitive on earth — not even our eye-lashes. And just as our eyes reopen after the first start, in the same way the Barberry stamens slowly return to rest, but ready to instantly spring back again. This sensitiveness serves its own peculiar purpose, which leads us into a wholly new field of plant life, and one which I can barely touch upon here. There is no better method of making this honey-loving guest serve as an unwilling transporter of the fructifying pollen than to thus shake it upon his hairy head. This brings us at once upon one of the most profound riddles of plant life — sensation in the service of a wonderfully intelligent contrivance. No other portion of a Barberry bush is sensitive, save just this one portion where it is necessary.

The same mystery that lies concealed here meets us again in our investigation of other field and garden flowers. The Portulaca has similar sensitive stamens; in the cactus garden, the blossoms of the prickly pear (*Opuntia*) please us in the same manner; in the fields, the chickory and corn-flower; in the vegetable garden the artichoke; on the high-way the knap-weed, thistle and many others show us the same phenomena.

The nature lover who follows this line of investigation can make many discoveries, for we

are here but at the very beginnings of our knowledge. The flowers everywhere give the same gentle yet energetic response to our touch: they strew the assailant with pollen. Indeed this poetical response shows that they are not fitted for such great clumsy fingers as ours. It may be somewhat painful to the nature-lover, but we are forced to admit that the flowers do not bloom for us. They adorn themselves in maidenly beauty for the marriage ball. The matchmakers are the butterflies, bees, flies and beetles, that do the work of fertilization in return for the hospitality of a meal.

We cannot but marvel at the strange fact that at the very moment when the plants need to act they reach out as with ghostly threads into the activities of life. I scarcely can blame those who ascribe such mysterious actions to some elf or fairy, who dwells secretly within the blossom, and suddenly beckons to us with graceful hand.

All this is really so marvelous that I can not avoid citing another example — and especially since it is one that can be observed almost anywhere from spring to autumn. I refer to the pretty red centaurey, or star thistle (*Centaurea Jacéa*) that forsakes us only after the leaves have fallen. Its touseled purple head of flowers is

familiar to every one, even to those who do not know its name. Closer examination shows us a strange crown of empty flower husks, tiny blossoms that bear no fruit. The botanist calls them the exhibition apparatus, a sort of startling costume intended to attract the attention of six-legged passersby. In the centre, however, stands the good mother, inconspicuous — but fruitful. These decorative parts conceal a white thread, the pistil, around which are five stamens whose tops are grown together into a tube enclosing the pistil. If one of the stamens is touched they draw themselves together as if burnt and the pollen puffs out and sticks tight to the intruder. The same end is here reached, but by wholly different means than in the barberry; which teaches us important lessons. Nature does not work according to any scheme, but with reference to the circumstances of each special case. We call this adaptation, and the greatest scientists agree that it is just this capacity for adaptation that distinguishes the laws of life from those of death. These laws of life do not express themselves alone in the closing of the leaves at night, in the circling movements of the buds, and tendrils, nor in the activities of the blossoms, but every portion of the plant shows us beyond dispute that

it too lives,— if in no other way, then in its hunger for the life-giving light. The green portions of the plants can feed only by means of the light, and therefore they hesitate at no exertion in order to reach the light. The little flower gardens with which we decorate our windows offer an excellent opportunity to study this. The geraniums, fuchsias and foliage plants are all looking out of the window. None of their blossoms bow to us; all greet the light, and even the buds of our climbing vines creep along the wall to peep inquisitively out of the window. Our most petted plants turn their backs on us and our room. This is so common that we never notice it. When the question is asked as to why this is so, there comes but a single word in answer, it is the light-hunger — heliotropism — the scholars call it.

This heliotropism affects nearly all plants, causing them to always turn toward the sun. To be sure the plant-stalks are always growing (as can be seen in the houseplants) — but their growth is always towards the light. The leaf-stalks many times twist themselves in the strangest manner in order to hold their leaves perpendicular to the light. Exhaustless are the

exertions and the methods adopted by living things in order to satisfy their light-hunger.

Many flowers practice a sort of dumb sun-worship — with their flowers and leaf-discs looking ever upward to the sun — in the morning they greet Phœbus in the east, and at evening they look yearningly to the west. When the sun goes down or hides behind storm clouds they hang their heads in sorrow. It was just on account of this that the flaming yellow discs of the helianthus are popularly called sun-flowers — scholars were long doubtful if its daily changes in position were really following the sun — of late, however, they have become convinced.

When we consider this fact we are struck with the frugality of mother nature. It is not without cause that nature is called mother — she is generous but economical, as a good mother should be. She does not spend an atom more of life energy than her creatures require. Once this is understood it becomes the central thought of philosophy.

The plants perform just exactly as much movement as their life demands. We know now why they are ordinarily still and restful — their simple life demands no other exertions. If they can not help themselves otherwise, however, they

do not hesitate before a continuous, tireless, even violent activity, if necessary they spring with the lightning speed of an animal.

There are certain insect-devouring plants that justify all these somewhat incredible assertions. With the animal method of gaining a living come also the animal desires and activities.

One of these robbing and murdering plants with the poetical name of the sun-dew (*Drosera-rotundifolia*) is not difficult of access to the nature lover. It is to be found in many of the fields and swamps of Germany;[1] moreover they can easily be grown in the garden if desired. On the upper side of all the little plate-shaped leaves of this plant, there are short hairs tipped with something that glistens in the sun exactly like a drop of dew. Stiff and motionless they stand like antennæ. It is only imagination, but if such a thing were possible we would say it was listening. And truly woe be to the unsuspecting gnat or curious fly that seeks to steal sweets from this tempting glittering drop of dew. Its little head sticks fast in the tough sticky substance; wherever its tiny feet touch one of the treacherous lime tipped hairs, it only soils itself more and more and is the firmer held.

[1] And also of the U. S.—*Trans.*

The Sun-Dew (a carnivorous plant) catching an insect.

The feelers in the meantime are seized with a definite activity. After a few minutes one row after another, with slow but inevitable certainty grasp for their prey until, after between one and three hours nearly all will have seized the unlucky insect whose fate is now decided. If a larger insect is captured, such as an ant, a spider a beetle or a thousand legged worm, then the whole leaf rolls around it in order to secure its prey. And if by accident a dragon fly grown damp and weary, or a butterfly, falls within the grasp of this murderous plant, then follows what seems almost incredible — the other leaves, "smelling the meal," draw near, grasp at the prey and assist each other in the heavy task of overcoming its resistance. Once this is done the meal follows. Externally there is nothing to be seen, but after a few days when the tentacles (as they are actually called) release their hold, and the little meat plates expose their glistening surface, nothing remains but a dry skeleton to be blown away by the wind. Flesh and blood have been sucked away, for the tentacles are not only mouths but stomachs. When this almost incredible thing is studied closely — the tireless Darwin has done the principal work here also — it s seen that all these flesh-digesting plants se-

crete a sap containing the same digestive fluid as our own stomachs — pepsin — with which they surround the bodies, which are later sucked up as in our own stomachs. These beings stick their stomachs up into the air on handles.

There are more than 500 varieties of these carnivorous plants, and this name is more nearly correct than that of insect eating, which is commonly used, since they will also eat beef. The methods and contrivances utilized in the capture of the victims are inexhaustible. Sometimes there are tentacles, as with the sun-dew, sometimes the leaves wrap around their prey, as with the bladder-wort (*Pinguicula*) or sticky hairs are sent up as in the fly-catching *Drosophyllum*, that in many Portuguese farm houses very effectively fills the place of our disgusting fly traps. In addition there is a whole mass of beautiful mountain rock plants similarly occupied, such as the Deptford pink and the pepperwort (*Lepidium*). Many of the most beautiful of the primroses and the mountain saxifrage in case of necessity utilize their sticky appendages to capture insects from which to prepare a banquet. In the tropics they grow to a most horrible uncanniness, with great pitchers set with inward-pointing thorns as in the *Nepenthes* and *Sarra-*

cenia families, which the plant lover can often see in the hot-houses of botanical gardens. The bottoms of these vessels are often thickly covered with rotting animal bodies, so that the stench of putrefaction proclaims from afar the proximity of these murderous plants.

ALDROVANDA VESICULOSA,

which catches water animalcules in its leaves.

Although our sun-dew and bladder-wort are able to move but slowly in seizing their prey, yet there is no lack of rapid action when it is necessary.

There floats in our shallow ditches and ponds an unnoticed, insignificant looking plant in which one of the greatest wonders of nature is revealed. After the old Ulysses Aldrovandi, who three hundred years ago spent many years in jail as a heretic, but who nevertheless has wondrously opened the beauties of God's world, this plant is called *Aldrovandi vesiculosa*. It is not firmly rooted, but swims freely about, sailing, as the wind may blow, through the water with its muscle shaped bivalved leaves. All unsuspecting the animalcules of the swamp swim about it — the water-fleas, skippers and mosquito larvæ,— but scarcely do they touch one of the bristles extending out from the muscles, when both scales are clapped together, to open only when the prisoner has been digested.

The most remarkable sensitiveness, however, is displayed by the American Fly-trap, which has indeed become proverbial in this respect. Woe to the insect that touches the inside of one of its two-lobed leaves. Like a flash the two lobes come together, the long sharp teeth along their outer edges grip one another in a grim trellis work, and from this imprisonment there is no escape.

The walls of this fearfully ingenious prison then exude a caustic sticky fluid that devours, in the fullest sense of the words, "hide and hair" of the victim.

The American Fly-Trap (*Dionacea*).

Illustration after illustration might be piled up of slow and imperceptible as well as sudden

striking movements of plants. But those already given are amply sufficient, and all the more so since any such study of nature constantly opens new views, of ever more intense interest, because they reveal to us another life than that which we commonly recognize in ourselves and the animals.

In investigating these movements it has been discovered that plants *smell.* This does not refer to the puzzling movements made by the rootlets in search of water — which enables the plants, like some monkeys — to discover water without the use of the power of smell, but as Count Solms-Laubach has discovered, certain parasitical plants can recognize the slightest trace of the odor of their victim and, overcoming all obstacles, will crawl directly to it,— something almost incredible had it not been proved over and over again. In the hemp-raising districts, there is found every year a strange flesh-colored and also flesh-appearing substance known and feared by the farmer as hemp-death. This growth, which the botanist calls *Orobanche,* lives from the sap in the hemp roots and with unfailing certainty it turns every one of its subterranean sprouts in the direction of these roots.

The flax-dodder (*cuscuta*) acts in a similar

The Flax Death (*Cuscuta*), which lives from the sap of other plants. Its germs (at lower right of cut) grow in the direction where a plant is to be found from which it can obtain its sustenance. (Somewhat enlarged.)

manner. Its fine pale white silky threads reach out like murderous tentacles embracing leaf after leaf, and like the Empusa of antiquity, killing those whom it kisses. Its tender shoots creep, tasting and testing, like a little yellow worm about its whole surroundings until it comes to another stalk to which it can cling. In damp woods we often find in early spring a still stranger pale odd colored sponge-like object. Every forester knows and hates it as a murderer of trees. It is the toothwort (*Lathracea*) which lives from the sap in the roots of the poplar and some shrubs. This sponge-like object also smells out its prey — yes, even more, it is the most malicious murderer that human phantasy has ever conceived. All of the terrible tales of strange horrors concealed in subterranean caves are here actually realized in miniature. Under the leafy covering of the great forest floor things are happening that few will believe until they have seen them with their own eyes. To be sure they are so small that a microscope is needed to examine into their actual workings. However, they are no less interesting on this account. If we take hold of the faded looking stem or scape of such a toothwort and pull it out of the ground we shall discover first, that it has

an extremely long underground portion consisting of a thick stem closely set with fleshy discolored leaflets. What are these scales? Looked at in the light they are seen to be the most intricate sort of murderous traps that could be conceived. In the miniature world of the microscope they constitute an actual Cretan labyrinth with a veritable Minotaur in the centre. Each one of the scale-like leaves contain numerous tiny holes that wind around and have a very minute opening to the outer world. These form the grandest sort of hiding places for little animals of the humus earth. Whoever has closely examined the ground in the forest shadows know how thickly populated it is. Little black springtails hop back and forth, plant-lice and minute spiders creep cautiously around, tiny beetles and mites stream in and out of the countless cracks and rifts that lead into the earth. Anyone who looks at a bit of damp leaf mold under a microscope can not fail to be astonished to see how thickly it is populated with thousands of radiolaria, water-bears, hair-worms, rhizopods, infusoria and amœba. Nature is always the greatest in the smallest. And the whole crawling host, whose single life-work is the transformation of the decaying mat-

The Toothwort (*Lathræa*), in forest humus attached parasitically to a root. At the lower left is a section of the stem with scales, which is also pictured in longitudinal section through the scales. To the right is an enlarged section of a single scale. To the extreme lower right is a highly magnified cut of one of the glands and the threads with which it grasps its prey.

ter into utilizable life elements while they devour it, — this many colored protection-seeking host, are sure to make use of such a convenient home as is offered by these little caves in the scales of the toothwort. They hasten inside — never to return. What a little drama nature there plays down beneath the surface of the earth! From the walls of their dwelling tiny arms like the tentacles of some minute octopus, reach out, and greedy feelers seize the shelter-seeking mite and greedily suck out its life juices, and when they have finished, disappear in the walls, as ghost-like as they came.

Is such a thing credible? It is only necessary to take a little trouble to see it for oneself as I have done. A little slit through the wall of such a leaf cavity shows little tongues and wee structures looking like the head of a pin. From out of these the living portion of the plant reaches for the passing guest; if necessary every cell becomes a beast of prey and feeds itself. These facts, only discovered within the last few years, are so strange that many things are not yet understood about them.[1]

Only the facts themselves are positively known

[1] Similar phenomena have been observed in the Alpine plant *Bartsia*.

and these furnish the strongest proof of a sort of inner life in plants that opens to us hitherto undreamed of horizons. There are inner movements, a strange circulation in the bodies — as in our own — of which we as yet know very little. Only here and there does the veil lift. The interior of the plant cells always contains a mystical tranquil stream. Recently it has been discovered that this stream appears only when the body is injured, and also that when a leaf or a blossom is torn, a movement as of pain goes in a wide circle around the wound through the many chambers of the plant body. Their contents move from one wall to the other; and it has also been discovered that the little green discs to which the plant owes its color are attracted by the sunlight as by a magnet. When the light strikes them they creep to the illuminated side of their cells. When darkness comes they creep back. But all these things are still little understood. We imagine rather than know that there is an internal life of the plants with capacities, powers and processes that reach down deep into the regions where our sense, our intelligence and our imagination have their boundaries. Who knows what possibilities of knowledge lie here?

Out of this endless abundance of experience

there necessarily press new convictions. Creatures that react so certainly, so variously and so promptly to the outer world must necessarily have some such means of communication between them and the outer world as with us are called *senses* and *sense organs*. Think once more of the rootlet ends. What a manifold activity we have learned to recognize in it. And yet if we observe it in its life we shall continually find new surprising features. It responds not only to external shocks — lifeless objects do this also to a certain degree — but it responds in a suitable manner from within itself, it develops and utilizes independently the received impression, more limited in its expressions than the animal to be sure, but essentially the same. Only by such considerations can we explain why the absorption cells by means of which the rootlet takes up the mineral substances dissolved in water, are formed only where they are required. When in its wanderings in the earth it comes to gaps — it often has to make long subterranean trips — it never attempts to form suction cells in such places. Even more, the root structure corresponds to the amount of water evaporated from the leaves, and the roots reach out or are contracted or the suction cells restricted

to correspond to the demand made upon them. Compare in this respect the beech and the pine. The leaf of the first will evaporate daily six to ten times as much water as the pine needles — consequently the whole soil underneath the first is a thousand times undermined, while the pine forms no such structure.

Such systematic co-operation would not be possible, if the tree is not completely aware of all that takes place in air or earth and was not able to adjust itself to whatever affects its life. In animals we call the same characteristic sense perception, why should we not give it the same name in plants. *Plants must have sense organs,* is the only logical conclusion from the previously described facts.

To be sure this will cause many a shake of the head before it will be rightly understood. When the word sense organ is used we naturally think first of our eyes or of the wonderfully complicated apparatus of our ears. Such things are certainly unthinkable in plants. But how about such a sense organ as ours of taste. Is it not simply a tiny papilla on our tongue, a little peg into which a nerve fibre runs. Perfectly simple, and yet it opens to us all the manifold pleasures of the table. To know just how perfect

such a taste point is, question some old tippler, who with unfailing certainty knows how to distinguish the slight variations in tastes of different vintages, which are imperceptible to the analyzing skill of the chemist.

We are apt to forget that the wondrous mass of our impressions, is due, not so much to the complications of our sense organs, as to the incomprehensible capacity for differentiation of our receiving apparatus. Whoever has investigated the lowest animals — insects, crabs and worms, know that the simplest eye is only a colored-spot with a nerve, the simplest organ of location a bladder in which a kernel of sand rattles, and how the sensation of a beetle can be aroused only through a few hairs whose roots enclose nerve fibres.

The capacity to perceive the relations of the world in terms of nerve-irritation, and to direct life events thereby is called sense, and every apparatus that accomplishes this is a sense organ, whether it be a tiny hair, a spot of color or a highly developed, vitally functioning photo-camera.

Once these considerations are admitted we are able to comprehend the sense life and sense-organs of plants.

They must be extremely simple and inconspicuous, otherwise they would have been discovered long ago. This is by no means necessarily true of the sense capacities. All that we have spoken of hitherto in this work shows this. They are not simply conspicuous but of a delicacy that we can not measure.

The plants are infinitely more sensitive in many directions than man. Things that to us are mere air affect them; conditions that we are unable to perceive attract them and stir them to action. Darwin found that the glands of the sun-dew were excited when a piece of thread was laid upon them weighing only $\frac{1}{78740}$ of a grain. That would be but air to us. Bacteria can taste the billioneth part of a milligram of potassium salt. If the leg of a fly be laid in a large dish of water the spores of certain fungi will swim swiftly from a considerable distance to the attractive repast. A tendril that, next to the rootlets constitute the most sensitive portion of plants, will bend if a piece of silk thread is laid across it weighing but .00025 of a gram — we can not feel ten times that weight. Only in one sense are we on an equality with the plants — that of smell. Man has not yet been able to weigh the atom of musk that our nose will

quickly perceive, and the astonishing powers of scent of those mammalia that are compelled to seek their sustenance by the help of their nose has lately been told us in the excellent book of Dr. Zell's.[1]

Equipped with this preliminary knowledge, and recognizing the necessity of the greatest possible caution, because of the delicacy of their sensation, we can examine into the sense life of plants. It will reveal to us one of the most entrancing pictures of modern natural history. During the last decade, under the leadership of those two great plant physiologists Sachs and Pfeffer, advances have been made in the knowledge of this concealed life of our woods and meadows, which slowly but with ever more imperative necessity demands the entire revolution of the old fantastic speculations concerning vegetable sense-life.

The actions of plants in relation to their light sense are most incredible. This sense is so extraordinarily fine that leaves growing in the dark will perceive differences of light so small that they will not affect even our scientific apparatus. But it is not that they simply perceive light better, but much more of it than we. The violet

1 "Ist das Tier Unvernünftig?"

and ultra-violet rays, that for the human eye fall into a twilight fading into darkness, affect leaves and flowers the most, while the red which painfully over-irritates our eyes, scarcely affects

The fungus (*Pilobolus*), that shoots its little black spore heads towards the light.

them at all. The differences in light rays, which come to our consciousness in the form of colors exist for the plants also. Experiments which

have been made with colored light upon the simple freely moving vegetable growths have thoroughly proven this point. They are even sensitive to the source from which the light comes. There is a little fungi, an uninviting fellow as to his appetites, since he lives off horse manure, but poetic and attractive in his appearance. Fresh as dew, glistening like a diamond, looking as if woven from a breath, it raises its raven black head proudly in the morning, and during the forenoon throws itself with a sudden movement far into the air. Then it collapses like a breath of mist and its life is ended. The next morning, however, there stands another shining head in the same spot. This little fungus, which the botanists call *Pilobolus crystallinus,* always points this little black head, in which the spores are located, towards the light. If it is placed in a darkened room, with but a single small opening for the light a delicate bombardment is heard through the whole forenoon. Every little spore head is shot at the spot of light, and by this means the tiny fungus proves that it knows very well from what source light comes.

The fanciful philosopher Fechner once offered the poetical suggestion that the plants communicated with each other by means of their per-

fumes. To be sure this is not true, but if it were true there would be but one subject of conversation that would run throughout the whole forest: "How are you getting on for light?" Light, light, light! every leaf appears to call as it turns and twists its stem in order the better to enjoy the life-giving element. I need only refer to the plant table where every leaf is striving to turn its disc perpendicular to the light, that it may absorb all that is possible. The forester too, knows right well how necessary thinning and opening are for the forest. No tree can exist without the necessary light.

But not the whole plant body is sensitive to light. It is only the leaves and the flowers that turn with such beseeching eagerness toward it. A twig or a stem is indifferent, and the roots will have nothing of it, turning shyly away into the dark earth. This problem, apparently so simple, becomes constantly more complicated the more we experiment. Once it was thought that the whole matter was solved by the simple statement that the green portions of the plants required the light in order to further their chemical processes of nourishment and respiration,— therefore they sought it. But how far this statement is from the truth! Just as far as the chemist is from

life! On closer investigation it was found that there was a puzzling Something which entered into the chemical process, Something within the plant that regulated, ordered and determined, Something upon which it depended whether this portion of the plant utilized the light which it needed or not. Something that stood above simple utility, and indeed often rejected, a present advantage in order to serve a higher need. It was observed with astonishment that plant life is no mathematical problem, as was once asserted in the frothy pride of first knowledge — two times two, in life, does not always make four, but if the material happens to fill the conditions, the process is many times interrupted and the factors diverted elsewhere. The plants can reckon for themselves and often draw a line across our reckoning. The green leaf stem needs the light as much as the leaf-disc, yet it does not seek it, but places itself modestly in the shade, through a " quiet calculation " that always maintains the leaf perpendicular to the light. Why does the light so differently affect two almost identical portions of the plant? We do not know. What is this puzzling Something that shows us its features for a moment in these simple phenomena? We natural scientists are seek-

ing for it with all eagerness, but up to the present time no one can say. Momentarily we get along with a phrase, by saying it is "Life." It is this which determines that all parts are not sensitive to light, that assigns to the leaves the reception of light, and to the stems their task and to other organs sensitiveness. When we come to consider this we shall find that behind it all there is a deep purposefulness. For what would become of the plants if all their parts sought to stand perpendicular to the light? The leaf would be in everlasting conflict with the stem and both would suffer. But as things are now the whole plant is so directed as to utilize the sun's rays in the best possible manner. The different parts have subjected themselves to a higher purpose: to the furtherance of the best existence. This in the latest natural science is called *teleology,* a misleading and much-abused word, and one easily leading to unscientific conclusions, but from which it is impossible to escape, and that will govern the scientific investigation of the future until its cause is understood.

Just how misleading it is we have an example in the fact that because of it, we have almost forgotten our subject of the light sense of plants. There is still one question to be answered. If

all portions of the plant body are not equally sensitive to light, which are the most so?

The leaves are most sensitive; the young leaves especially, and the tips of the first leaves most of all. The last is like a little primitive eye, like a sense organ. When a ray of light strikes it, the portion of the leaf which is touched curls towards it. At least Darwin found this to be true of the germinal leaves of oats.

Is it not a strange thought, that the thousands of little sprouts with which the meadow is bedecked in early spring are but so many eyes looking eagerly to see if the sun is not coming soon.

Whether the tips of the leaves are the only places that are especially sensitive to light is questionable. It does not seem probable to me. The developed organs of the plant need the light also. It is this which later determines their position. Where these sensitive places are, what is their nature, we as yet know nothing.[1] It has been suggested that perhaps the colors per-

[1] At the last meeting of the Scientific Society, in 1904, Prof. Haberlandt has published the results of some late investigations from which it appears that in many leaves the upper cell-layer acts like a concentrating lens, by which the light is focused in the middle cells, and in this way the position of the plants towards the light is determined. It would thus appear that the upper surface of the leaf is a sort of simple faceted eye, which in many tropical plants even has a sort of special lens.

formed this service. What good are the manifold colors of Flora's realm? Why is this bewildering wealth of colors strewn over meadow and forest? We remember to have already discovered that "only the necessary happens." For what is the color display of the flowers necessary? The old answer, once given, that the colors serve to lure the insects needed for fertilization, has partly lost its value. This is especially true since it has come to be known that many of the flower-visiting insects are very weak sighted. They are lured much more by the perfumes, which if the colors could make good their claim in this direction must be considered wholly superfluous. Perhaps the colors do not lure at all — for it has been repeatedly proven that bees and wasps continually scorn the most naturally colored artificial flowers. And certainly, even if we did not have this illustration, it is wholly immaterial for the purposes of fertilization, whether the leaves be sprinkled with dark or light, or whether the blossoms bear manifold stripes, dots and designs, or leaf-stems and stalks are colored red. The ferns and mosses that multiply by means of spores, the pines and the firs, which are indifferent to the insects, since the work of fertilization is per-

formed by the wind, still have quite strikingly colored yellow or red sexual organs. Why are the ocean algæ, deep on the bottom of still inlets, decked out in a wealth of gay colors, beside which the autumn beach forest is grey and uniform? There is a problem. The zoologists know that in the lowest animals the places most sensitive to light are generally marked by some colored stuff, a red or black particle, which naturally suggests the thought that the otherwise unintelligible display of colors, might perhaps serve a purpose in light sensitiveness,— perhaps only in the sense that the colored places serve as screens for the light in order to cover up certain chemical processes that light might injure. For us all this is only imaginings and conjectures, but it shows the wealth of discoveries that await our children. Goethe said once to Eckerman, "There is no greater joy than that which comes from the study of nature. Her secrets are fathomless, but to man it is granted to obtain ever deeper insight therein. And just because they must always remain inexhaustible, they have an everlasting attraction for us, that draws us constantly back to seek for new views and discoveries."

The true content and meaning of these words

full of noble and true scientific modesty are fully comprehended only when one returns from such a fruitless, yet attractive thought excursion as that we have just finished.

But we must leave this interesting point of view and go on. I will only permit myself to call to mind that we have discovered at least one sense organ in plants. This is the ever burrowing, yielding, water-seeking rootlet tip. "It is positively geotropic, hygrotropic, and stereotropic, and negatively heliotropic," says Fachman of it. What these mean we have already learned: it follows gravity, seeks water, clings to the surrounding matter and flees from the light. Could it do this without being sensitive to all these influences,— gravitation, water, earth and light? No. It was not without reason that Darwin declared that such a rootlet is the most wonderful thing on earth, and compared it to a little brain. This has been disputed: one investigator (Czapek) endorsing this idea, the other (Piccard) denying it, but no man can deny its marvelous sensitive capacity.

Moreover we must admit that all these various forms of sensitiveness are unthinkable without the capacity to receive them, and that throughout the animal world, even with the

simplest creatures there is a constant endeavor to transform certain bodily portions to adapt them to receive sensations, and that therefore, perhaps in the identical life of plants similar adaptations may be sought. An Austrian botanist, Count Professor Haberlandt, has succeeded in discovering a number of such *vegetable sense organs.*

A microscope is necessary in order to recognize them, for they are so fine and delicate, that like the human organs of touch, taste and smell, they can be hidden under our very eyes. We must now turn our studies toward the finer structure of the plants which in thousands of chambers and threads makes the living substance into an endlessly complicated mechanism, and in order to explain this I must refer to the accompanying illustrations upon which, magnified an hundred fold, every delicate portion is shown, and into which, with the latest apparatus, the plant structures can be analyzed. We meet some old acquaintances here. The agile, springing filament of the barberry, the eagerly reaching filaments of the knap-weed, the intelligent grasping tentacles of the sun-dew, the sensitive mimosa, and the greedily reaching gourd tendril.

We are now in a certain sense considering the

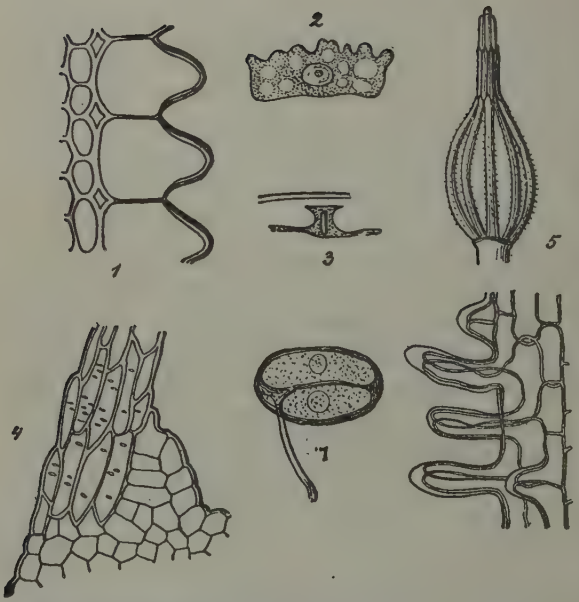


Fig. 1. Feeling Papilla on the stamens of the Barberry.—Fig. 2. Cell containing feeling papilla from the tentacles of the Sun-dew.—Fig. 3. Section through wall of feeling cell of gourd tendril.—Fig. 4. Longitudinal section of feeling bristle of Mimosa.—Fig. 5. The sensitive stamen of the centaury with hairs for feeling.—Fig. 6. A magnified hair from Fig. 5.—Fig. 7 Taste papilla from duck's bill.

very foundations of knowledge, entering deep into its structure, and looking into the development and the manifold architecture of its elements, as if into a glass model of a machine, that makes intelligible to us the otherwise incomprehensible technical explanation of a locomotive or a watch.

First of all there is the sensitive filament of the barberry. Experiments have shown that only the inner side, which is turned toward the pistil, is sensitive. And if we peel the skin off this side, which with a little care comes off as easily as the hide of an animal, and place it beneath a microscope, we see that the many-cornered flat divisions, which make up the customary cell arrangement of the skin, are interrupted at this point with some other structures. Little protuberances stare up at us, which owing to a circular thinning of their walls are to a certain degree movable, as though hung on hinges. This is the whole sense apparatus. It is so inconceivably simple that it may easily deceive us. But we forget that for the human sense of touch — and that is what this apparatus serves for — there is nothing more than a portion of living matter, that can be irritated by pressure. We forget that in the marvelously complicated mir-

acles of nature, in the mammals, and even in ourselves, sensitiveness is accomplished by just such a simple kernel. The tip of a duck's bill is one of the most sensitive things known. It is not for nothing that the ducks are constantly touching everything with it. The accompanying cut shows us the entire touch mechanism of the duck. It consists of two cells, which together form a small lump, to which a nerve runs. This is as simple as anything well could be.

The organs of feeling in plants are but variations on this very simple form. In the sensitive stamens of the corn-flower this organ consists of a circle of irritable hairs, in the knap-weed of upright scattered hairs, which play the same role as the " whiskers " of the cat.

The puzzle of the movements of the sun-dew is cleared up in the same manner. Only the sticky tops are sensitive, and on the cells of their edges it is possible with great care and patience to discover fine protoplasmic points, which require but an almost imperceptible irritation to awaken their sensitiveness.

Even finer yet is the irritable mechanism of the sensitive tendril. Sometimes only on its side, sometimes circling around it, but always somewhere we find the skin thickly set with a

very curious arrangement of cells. The rather thick walls of these cells are furnished at certain places with a tiny depression, in the external side of which there is a little sharp crystal deposit (probably of oxalic acid). When the tendril rubs this on any firm substance it presses the "thorn in the flesh" and spurs activity. It is the same refined form of irritation which compels the gentle movement of love in the cold-blooded garden snail. Just as here, the so-called love arrow of the snail is a little rod of lime, with which the snail pricks his own flesh in order to arouse the otherwise dormant sensitiveness for the opposite sex.

Of a wholly different sort are the sense organs connected with the sensitiveness of the mimosa and the lightning-like closing of the fly-trap. In the mimosa, it is easily visible from the outside as a joint-like thickening on the lower end of the leaf-stalk and stems. It has long been known that a touch or jar caused the sap, which is richly supplied to this portion, to move towards the outside, so that a change of pressure caused movement of the stem.

Even after we know this we are still in the dark as to how it comes about that just at the proper moment the lower portion of the joint is

squeezed out like a wet sponge. Haberlandt has recently explained this by his studies. He pointed out that on the under side of these tendrils there are little spurs sticking up that could not be wholly superfluous. They consist of firm dry material and are attached to a little cushion inserted between them and the tendril. The slightest pressure upon the spurs acts like a lever pressing the cushions together and forcing the water into the upper portion. This solves the question of the movement of leaves and stems. What an ingenious and original mechanism this makes! But how much more ingenious it appears when we consider its value and utility. Evidently it is very slightly adapted to excitation by rain drops or hail-stones. The hail could tear the leaves in pieces before a stone would touch the inconspicuous little spur. On the other hand the little mechanism acts promptly whenever an insect — a beetle, or an ant or especially a worm crawls up the stem for the purpose of reaching the delicate dainty leaves. The intruder can not avoid crawling over the spurs of the joint — but scarcely does he touch one of them when the trap is released. The stem raises, the leaves fold up and the assailant is either rolled off the branch by the unexpected

movement or draws back from his object in fright. And so Haberlandt thinks that the "modesty" of the mimosa is not so much a protection from rain as a cunning scheme of defense. If we are to believe him on this point then a large portion of our ideas about the "senseless mechanism of natural events" disappears. Yet we shall find many similar things in the course of our journey, and therefore we will reserve our comments until we make our final judgment on the sense life of plants.

There is for example the leaf of the fly-trap, possessing somewhat similar characteristics. It has similar *stimulators* as these irritation-arousing spurs are called, only these stand on the inner side of the two-lobed leaves. They are the most perfect sense organs known in the vegetable kingdom.

They form a joint that can close up like a knife.

This is surrounded with large cells whose thick outer wall bears a circular furrow. Here we see how carefully nature utilizes her material. Where the object demands there are walls as thin as a breath; where support is needed their walls are thick, sometimes of elastic pliable material, then of brittle hard cork, but always the

whole architecture is finely built and suitable, fitting errorless together like a machine, that throws all our inventions into the shade, since it lives and functions of itself. A little animal touches the tip of one of these spurs, the needle bends at the joint and the pressure this causes is transmitted from cell to cell until it reaches the leaf joint, when the water is squeezed out, so that the two valves come together, and all this much quicker than it takes us to tell it.

This shows us something of the so-called mechanical sense-organs of plants. Yet we have taken but a few glimpses into a whole great country that lies untouched by the investigator, and that offers rich discoveries for a little trouble. I believe that much can be done even by the amateur who throws himself into this field and observes the changing life phenomena of the plant, instead of remaining attached to the colored shapes and play with names, that now seem to hold almost every lover of the *scientia amabilis*. In the field of botany Darwin was but such an amateur, and yet how much we owe to him!

Naturally the question at once arises whether this is the only sense organ through which plants are connected with the external world. If

their formative power has sufficed to adapt them to the effects of touch and light, and to enable them to use these for the furtherance of their life, may it not be possible that they hear and taste, or perhaps have sense organs for things of which we know nothing? The naturalist dares not say of anything before-hand: It is impossible. It is just this which gives him the boundless breadth and freedom of attitude, in that he considers everything on the earth or in the heavens *possible.* But he *believes* only that which can be *known.* Certainly many strange facts are known concerning the sense organs of plants.

The whole riddle of gravity refers us to the vegetables as the best teacher, since they are intensely sensitive to something of which we are wholly unconscious. Otherwise such keen study would not have been necessary before a Newton discovered that such a thing as gravity existed in nature. Yet a glance at the forest furnishes the most conclusive evidence of its existence. There stands the noble fir tree, slender and "as straight as a fir," and if we take the trouble to test it with a plummet, we shall find that no builder can erect a wall more perfectly perpendicular than this tree erects itself. But often one

does not see the forest for the trees. Our scholars have recently been asking themselves how it is possible that every tree can teach us something the knowledge of which we can otherwise reach only through complicated calculations.

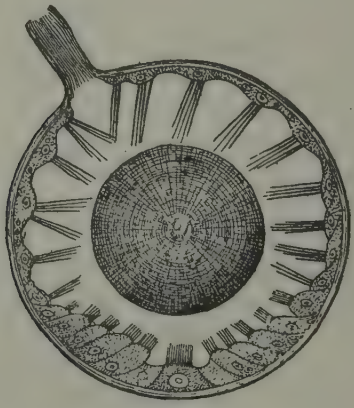
Three men have been the pioneers in this investigation. These are the botanists Noll, Haberlandt [1] and Němec.[2] The latest discoveries that we are discussing here are especially connected with their names, and it is but just that they should be mentioned. These men have said to themselves: if the plants are sensitive to gravity there must be some means by which this excitation is brought to their sensitiveness. Where is the intermediate organ? This at once suggests a comparison between the plants and ourselves. How do we recognize the existence of gravity? As for us we perceive it through nothing whatever. We are only aware of it through the medium of results and observations.

When, however, men began to observe closely the habits of life of the lower animals, it soon became evident, especially with certain water animals, that they were perfectly capable of determining what was above and what below, and of

[1] G. Halberlandt "Sinnesorgane in Pflanzenreich."
[2] B. Němec "Die Reizleitung, und die Reitzleitenden Structuren bei den Pflanzen."

placing themselves with reference to these directions. Their centre of gravity is not always so located that the mere distribution of weight is alone sufficient to keep their heads at the top, and yet they do stand erect. If by an accident they lose their equilibrium, they at once find it again. Every medusa, every little crab, every shell-fish, or snail, and the whole vari-colored host of sea-worms, all are perfectly capable of locating themselves in space. The more one thinks of this, the more remarkable it appears. No wonder that this problem has occupied many of the most able scientists. Because of the fact that none of these animals will endure being placed upon its back, but that it continues to sprawl and struggle, until with the aid of its feet, feelers, or contortions of its body, it has again turned itself toward the earth, it became evident that in some manner it was the attraction of the earth that showed animals their directions. But how? There was the puzzle. Finally the problem was correctly worked out from the theoretical point of view. If there was anywhere a sensitive place in the animal's body which was pressed by a firmly resisting substance, which was free to follow the attraction of gravitation, then it was plain that the animal would be able to tell

whether it was right side up or not. But was there anything of the kind to be found in the bodies of animals? This most astonishing supposition was found to be the truth. All the lower water animals, mollusks, crabs, medusa, and worms have an apparatus fitted for this purpose,



The location organ of the sea-snail.

only it is far more sensitive, and more practically equipped, than our intelligence has been able to discover. Turn for a moment to the cut given herewith. It is a section of the so-called location organ of a Mediterranean snail (*Pterotrachæ*).

A delicate bubble-like structure, with its inner walls thickly supplied with nerve-cells, which in turn are connected with a nerve. Each one of these cells carries a bundle of stiff bristles. In the middle of this water-filled bubble there is a little ball of lime. This little apparatus fills all the conditions that could be required for a gravity sense organ. The ball is freely movable, and constantly rolls towards the center of the earth, and in so doing irritates the little sensitive hairs, which in turn transmit to the snail the sense of proper or irregular position. Thus this animal carries a plumb-bob along with it.

The crabs have an even stranger arrangement. With them a few grains of sand function as a location weight. And the crab places these grains of sand in its own ear with its claws.

At first all statements concerning the operation of these grains depended only upon theory — the practical proof was furnished by experiments with water-animals from which these so-called *Statocysts* had been cut out. Crabs that were prevented from obtaining these grains of sand, were actually unable to any longer stand upright or go forward, but rolled over and were completely without sense of position, and would remain quiet if laid on their backs — until sand

was once more placed in their ears, whereupon they at once perceived their unnatural position and turned over. At the famous marine zoological station at Naples, experiments of this sort were made that gave very comical results.

Everyone that has spent any time at the seashore knows the pretty little shrimp. These also stick sand in the "Statocyst cavity." As they often shed their skins, in which case the grains of sand remain in the old skin, they must frequently repeat the process. They have sometimes been slyly placed in a vessel the bottom of which was covered with iron filings. Afterwards a strong magnet could play the part of the earth. When it was brought close to the animal, it arranged itself with relation to the magnet as it had previously done with relation to the center of the earth, and under these circumstances, swam with perfect satisfaction, either on its back or standing on its head. This was complete proof of the function played by the statocysts in animals.

Satisfactory results are obtained, when these experiments with animals are transferred without change to plants, and the search made to ascertain if there are no statocysts in flowers and shrubs. Naturally the first thing to determine is

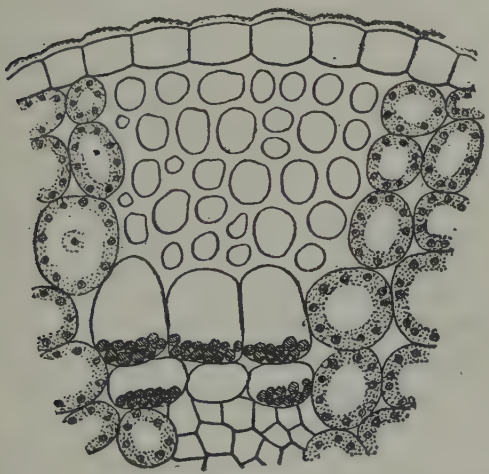
how the question can best be put. And this was: What portion of the plants are especially geotropic, that is, responsive to gravity? Certainly it is the roots and the growing stems and branches, for both are constantly working to stand erect. But how marvelous is the apparatus for the perception of these relations. Plants can not secrete lumps of lime nor use grains of sand, nevertheless they prepare, under the influence of the light, large quantities of starch grains which are stored away in especially prepared cells as reserve stock.

Young growing stems and the little cap that protects the delicate tip of the rootlets contain many such starch grains. In these cells they roll around just as freely as the sand in the ear of the crab, and the universal sensitiveness of the living substance of plants transmits the difference in irritation between pressure on the right and wrong side as well as the nerves of animals. In this manner Haberlandt and Němec have theoretically discovered the geotropic sense organs of plants. It was now necessary to prove this by practical experiments. I may be excused if I describe this experiment somewhat in detail, because it is a splendid example of the marvelous refinement and ingenuity with which the

modern scientist must work, if he will raise the veil that nature has spread before our senses.

Haberlandt theorized as follows: If these starch grains are really used as plumbs and levels, by which the growing things determine their position, then I must seek an opportunity to take this apparatus from them. If it is then helpless and no longer able to grow upright then my hypothesis is proved correct. My predecessor, Němec, was too rough with these lovely children. He confined their roots in plaster, but this injured their health and robbed them thereby of their strength, and because they were then no longer capable of responding to gravity, thought he had secured the desired evidence. But the poor things had only been rendered helpless by this terrible choking and consequently had no sensation whatever. Haberlandt therefore set about it in a more cunning manner. He waited until Fall, when he knew that the plants were laying up their reserve for Winter, and consequently must use the starch for other purposes. When it becomes cold in October earlier than usual, there are young shrubs that are curiously bent, and that stand around as if they were stupid or dizzy. He investigated these, and found that they had no starch kernels, but when

they were brought into a warm room these kernels soon began to grow, so that they were replaced in about twenty hours. When these facts are considered for a few moments it will be evident that they offer a most remarkable oppor-



Gravity sense-organ from the flower stem of an *Arum*.

tunity to discover the function of these starch kernels. The stems grew before the apparatus began to function, ergo, according to our theory this growth should be unaffected by gravity dur-

ing the first twenty hours. This was found to be the fact. The characteristic geotropic bending upwards did not manifest itself until the starch kernels were re-formed. It is just such detective work that we call scientific investigation.

But there was an unfavorable message that came along with this news. There are stems and rootlets that have free-moving starch kernels, and yet are not affected by gravitation. This has also its counterpart in the animal world. The graceful medusæ and actinæ that decorate aquariums are unusually sensitive to gravitation — so much so that they are the common school example — yet, so far as we know, they have no apparatus for that purpose. The mammals, including ourselves, have a sense of location. We also know where this faculty is located, namely, in the inner ear, with its remarkable chambers turned in three directions; for if a poor devil is injured there he can no longer stand up or go forward, and does not know whether he is on his head or his feet. But this labyrinth does not entirely correspond to our beautiful theory. It has neither rattling statocysts or grains of sand, and our wisdom has therefore apparently reached its limit. Because of these facts there has been

a merry war on the subject of "geotropic sense-organs," and whoever has the breath can easily get into a lively mix-up on the question. Such scientific battles, however, are productive only of good. They clear the way for new knowledge and prevent lethargy. It was only in the days when there was no science that scholars were satisfied and considered their systems capable of explaining everything. I hope that no friend and fellow builder of our scientific world view may ever forget the keen pessimistic words of Nietsche, that he speaks in his "*Götzendammerung.*"

"It is beginning to dawn upon five or six heads that physics are only a world analysis and description and not an explanation." The first commandment of the scientific thinker is: "Be bold in all hopes, but extremely modest in the acceptance of anything, no matter how thoroughly proven."

But we must turn away from the Heaven of hopes and conjectures back once more to the solid earth of facts — for our knowledge of the sense perceptions of plants is by no means exhausted. Even if we are as yet unable to discover any other sense organs in them, this may easily be due only to the incompleteness of our

knowledge, and not to the defects of nature. The hygrotropic irritation of roots, that turns them inevitably toward water, must have a corresponding organ, as yet unknown to us. The undoubtedly existing temperature sense of the plants, must certainly have its organ and the fine taste of which a thousand examples shows some plants to be possessed, must be denied if there are no vegetable papillæ of taste.

Naturally the question arises, how can we determine that the plants taste? That plants are sensitive to light is easily to be concluded, from the fact that they bend towards it, gravity stands them erect, and they respond to touches by movement. But it seems almost incredible that we can ever come to know whether anything pleases the taste of the plants or not. For taste has no meaning except in the sense of distinguishing good from bad tastes. But this can be discovered. Those pygmies of the vegetable kingdom, the bacteria (*schizomycetes*) are the greatest epicures in the world. They are sensitive to immeasurably small quantities, the billioneth part of a kilogram, of some substances, to such an extent that they rush from all directions when their "favorite dish" is set before them. They can be

allured to the most deadly poison if it but be flavored with this alluring taste. By many experiments we have come to know what is the favorite dish of most bacteria; it is potassium salts.

The objection may be made that this attraction is but the inherent impulse to take nourishment, which exists in every creature. But there are certain gourmands that disprove this. Glycerine, for example, is especially nourishing to bacteria, but they can not be attracted by it. On the other hand, each group has its own especial pet substance, for the love of which it will go through thick and thin, so far as such difficulties are found in a drop of water, offering its life with joy to attain its object. The bacteria certainly are remarkably fine connoisseurs, for they show aversion to all alkalies, and offer a striking example to all total abstainers by their abhorrence of alcohol. In saying this I am well aware that I am in danger of helping some hard-drinking hygienist to the excuse that he is taking the alcohol to drive out bacteria. Yet in spite of this I can not conceal the fact that many of the most feared bacteria can actually, because of a to us almost unrecognizable dilution of alcohol, have their ap-

petite for the most alluring meal forever destroyed.

But the jest soon becomes earnest astonishment on further investigation into the taste inclinations of the vegetable kingdom. The incomprehensible dominating purposefulness of taste looks at us here also with its puzzling eyes. Nature bestows nothing superfluous upon her creatures. The sense of taste is made use of in propagation. The beautiful art miniature of our woods, the world of mosses, is maintained by certain peculiar infusorial-like creatures, into which a portion of the moss is transformed. Certain cells develop long hairs, through whose lively movements they quickly move about in the drops of dew, which are necessary to their animation. These are the *spermatozoa,* that set forth on adventurous journeys through every drop of morning dew. Whither? Like a true troubadour they seek a charming female. They seek the countless delicate little cups, in the bottom of which the moss-egg is hiding and which can only develop into life after it has united in love with the strange *spermatozoon.* Just think for a moment what marvels the darkness of the still forest earth conceals. How do these eager searchers find each other? By what clever arti-

fice does the All-wise, which we know as Nature, know how to help these two together? Here it is that taste comes in. The spermatozoa know no more pleasurable taste than that of malic acid. In the laboratory they are often coaxed into little tubes in which a bit of malic acid is placed. And it is certainly not by "accident" but with a purposeful contrivance that the moss-egg also likes the taste of malic acid. Everywhere nature, with her wise "knowledge of life," uses taste to spur on the fullfilment of life essentials.[1]

But greater marvels than these are to be found in the quiet forest nooks. Above the miniature forest of the mosses, there rises a second delicate roof of leaves, the forest of ferns. They also send out moving spermatozoa for the purpose of fertilization, and these also are allured to the egg by the intense pleasure of taste. But how strange — the rain, which washes the spermatozoa of the mosses and ferns together, might easily bring about the worst sort of miss-marriages — it might marry the ferns to the mosses. But this is absolutely prevented. The spermatozoa of the fern are not attracted by malic

[1] Those who are familiar with the work of Lester F. Ward will note the close resemblance to his position that the attainment of "function" is always brought about by an appeal to "feeling." *Trans.*

acid — they demand cane-sugar. The egg of the fern also loves the taste of sweetened water. So each of the bridegrooms knows how to find his proper bride.

After such experiments it does not sound so completely ridiculous for the botanist to more earnestly ask himself the question whether plants do not hear. But, however attractive a picture our poets may conceive of the silent forest as listening in the deep noonday quiet, there is not the slightest atom of truth in the attractive metaphor. There is nothing whatever to show that plants hear in the sense that we do, and there is nothing to show that they could make any use of hearing. Nevertheless, it is not to be denied, that taken in the purely physical sense they may be to some degree sensitive to loud tones. The very existence of the statocysts must make them sensible, not alone to slight changes in position, but also to strong air vibrations, and it is not wholly impossible that they are much like the fishes in this respect, over whose hearing there have been so many disputes. The latter certainly do not hear in our sense, in spite of the Roman story of Crassus, who was said to call the eels in his fish tank by name — but they are nevertheless sensitive to very slight vibrations.

And in practice this accomplishes the same ends as our hearing.

So we are finally compelled, whether we wish or not, to compare this wonderfully delicate sense life of plants with human sense, learning thereby the better to know ourselves. Do we not find in the flower all that from which we construct the world? Feeling, tasting, smelling, seeing, hearing — do these not all find their equivalent in the touch sense, response to light, chemotropism, and sensitiveness to movements? And is it really something wholly different — or is it in reality but a sort of germ of human sensation? It is certainly just as fine, many times even more delicate, but still indefinite, perhaps more like a suggestion of sensation. And this makes it comprehensible to every one that the world, as it is pictured in our sense life, is not the reality, or at least not the essential being of the thing, but rather only one form of comprehending it. But there are other, and very many other such forms.

The plants for example, have such another. One of the most abstract thoughts of philosophy is thereby made clearly intelligible: our idea of the world is wholly subjective, and is of the pe-

culiar form that our sense organs construct. A few hairs, a lense, an opening more or less, and the world would be something wholly different. That is the natural science commentary upon Kant's great idea of the "thing in itself" *(Ding an sich)*, that stands behind the appearances.

When once we have comprehended the meaning of Helmholtz' classical saying: "The sense perceptions are only a symbol of the external world" — then we shall for the first time comprehend the naïveness of all realists, who think the world is really what we see. The plants can teach us that it is not so to them.[1]

The world must therefore be something different, because the plants observe things of which we know nothing. A Finnish scholar, Professor Elfving, ten years ago described a puzzling effect, produced from a distance, upon many plants by metals, whose growing parts inclined toward the places where the metals were located. There has been much discussion upon the subject, and the possibility of the fact doubted, but the facts were proved; and finally in recent times the

[1] Does this really say anything more than that there are some of the "realities" which we are not able to apprehend by our senses? Does it in any way alter the fact that what we do perceive are certain phases of the "thing in itself," and that there is no other "thing" than that which we perceive, but only other manifestations of it? — *Trans.*

study of Roentgen rays, of black rays and of radiology in general has showed that the life of plants is undoubtedly sensitive to those puzzling emanations, which to our imperfect understanding are apparently purposeless, but which certainly do not stream in vain through our atmosphere, the water and the surface of the earth, perhaps through our entire universe. We know nothing of such things by ourselves, and have always denied their existence until it has become possible for us to transform the original form of energy of these hypothetical rays into forms perceptible to our senses. To give another example: we are already familiar with the sleep of flowers, and we know also that it serves as a protection, and to prevent too rapid transpiration. This is nothing uncommon. We do the same thing when we wrap ourselves up and cower down when we are cold. But many plants accomplish much more than this, the flower-buds of the pansy, or the young umbel of the carrot, which hang their heads as if wilted at night, do not do this every night — "only when a cold night may be expected," the botanist tells us. This harmless little sentence may well cause sleepless nights for a thinker. The plants "know" beforehand when it is going to be cold

— is the first hasty thought. But when the matter is carefully considered, it will be found that it is much less of a "premonition" than a first message of the coming of the cold which does not affect our thermometers, but which is capable of affecting the plants, and to which they respond in their manner. Nothing shows more thoroughly how scholasticism is inoculated into us than the fact that we must always be warned that "There are more things in heaven and earth than are dreamed of in our philosophy." In an earlier time the words miracle and witch-craft were applied to what in these more enlightened days we call an unknown or poorly understood power of nature.

The plants certainly have fundamentally different sense perceptions from us. New discoveries prove this daily.

How can we otherwise indicate the problem that the latest natural science calls the "adjustment of the organism" *(Stimmung der Organismen)*. It is despairingly incomprehensible. The leaves of a tree are not all sensitive in the same manner to light; those of different kinds of plants are totally different.

The beech seeks the light — the richly smelling wood-ward growing on its stem loves rather

the half-darkness, like an oversensitive woman; the emerald green moss on the crevices between its roots hides shyly in a still darker corner. Thick around it spring a few strawberries, that twist and stretch their red-cheeked heads until they reach the single ray of light, which the leaves permit to fall upon them for a single morning hour. All of these creatures need the life-giving light, for they are all formed from the same life-substance, and yet each one can apply it only in its own way. They are each "adjusted" to a different amount of light, and ever so little more or less injures them. And not only this, but this adjustment varies, always according to circumstances, and from apparently identical causes.

The form of the "adjustment" varies; there are geotropic and chemitropic adjustments as well as those for the light. And it is noteworthy that this adjustment changes when the temperature increases, it changes as the plant becomes older, yes, it even changes when the plant has need of it. The delicate toad-flax *(Linaria Cymbalaria)* that in South Germany adorns the old walls with such a wealth of garlands, has attractive little violet leaves, that are adjusted to the greatest possible amount of light. When

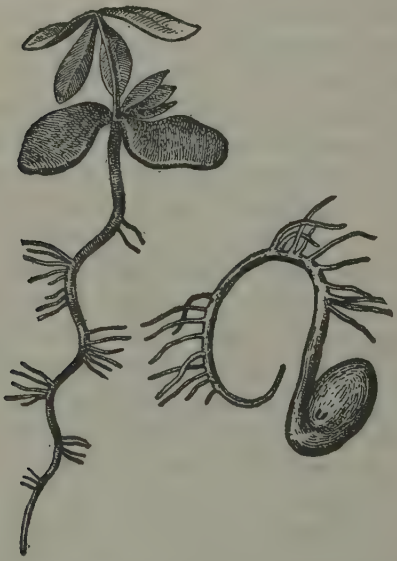
they have blossomed, however, the necessity for light changes, and the growing fruit seeks the shade in crevices between the stones. What are we to understand from this? Nothing, except that this change is of practical advantage to the toad-flax, for in the very moment that the seeds are ripe, it lays them cautiously and securely in the very place suited for their germination. We see here a confusion of all sorts of laws, of which we know little more than that we know nothing. It indicates an internal life of perceptions and causes, which pass through our own world of feeling without a trace.

Of such a nature also is the bodily feeling, or sensitiveness to form, which belongs to the latest discoveries in the science of life. For a long time it has been known that a portion of a plant, bent artificially, always strove to attain its original form. It was also observed that leaves, that might be twisted into the most unusual positions and prolongations of their stems, strove to regain their typical position. This was considered a curiosity, to be sure with the same justification that petrification was once considered a "freak of nature." But nature does not commit freaks. Now we know that behind these appearances there are laws. We have here a definite capacity

of the plant organism that is wholly absent from human beings, or which at least has not been discovered in us. To be sure we are still far from knowing all about ourselves. The plants are conscious of their bodily relations, at least this is the natural conclusion from the fact that the characteristic external form of the plant is restored through internal forces whenever it is forcibly destroyed. This "characteristic exterior" is also an incomprehensible "something," that every one knows who is concerned with plants, yet which no one can clearly explain. Like the "air" of a gentle lady whose appearance the parvenu woman may imitate in the greatest detail, without ever attaining it, it is something that is clearly felt, but of which it is hard to tell on what it rests. The practiced observer knows from afar the plants with which he is familiar, without seeing them closely and without knowing how he recognizes them. By its "general appearance" he answers, if we question him about it. This total impression of the exterior, is typical for each variety, and consists of a certain orderly arrangement of leaves, stems, twigs, blossoms, and fruit, of a form and symmetry, which one feels and recognizes, without being able to logically analyze it. All living

creatures have this so that even the very short-sighted can recognize their acquaintances by means of it.

This "air" is replaced even when woods and



The form-sensitive roots of a young pea-plant.

fields are torn to pieces by a storm, or when a flood has destroyed the pleasant harmony of forms. Just one significant suggestion of the

explanation. This appearance proceeds from the fact which was first observed a few years ago, that the location of the branch roots upon the trunk root was not entirely determined by the dampness of the soil, the security of position, or the taking of nourishment, but had a certain definite relation to the main root. As a general thing this central root winds about somewhat and is variously curved, since it is compelled to make its way through the soil and amid various obstacles. The side roots, however, always spring from the convex side of the curves and never from the inside. In a wholly similar manner all spurs, side-branches and leaves are arranged in a definite fixed relation forming long or short spirals, which also holds true of the parts of all blossoms. The botanists of our fathers' time, and the school-teachers even of to-day, lay much weight upon the senseless figures describing these leaf positions, which were wholly unintelligible to them. But at a single stroke this tiresome calculation sinks back to what it actually is, mere play, when we recognize the vital laws that are manifest in it. A noble harmony rules all living beings, and impresses a feeling for itself upon all living objects.

Perhaps the feeling for this form also exists

in our consciousness; at least I may properly justify this by a reference to a remarkable phenomenon, that to my knowledge was first made known by the famous physiologist, Pflueger, and has since lapsed into forgetfulness. We can feel only a portion of our bodies at a time, and this only when a definite spot is affected. If one thinks, with closed eyes, fixedly on his middle finger it will not be more than a few minutes before he will feel a slight pain in it. Try it once. We only know that we have a stomach when it aches.

Moreover, just as we possess internal senses of this sort, which bring us such information, we must conclude from a theoretical argument that other living creatures have them, ergo, the plants also.

But this line of thought will bring us no further than to a theory. We know nothing of any internal sense of the plants, further than that it is a logical necessity, and will some day be discovered, just as the existence of the planet Neptune was known long before Leverrier discovered it.

The unknown which our faculties are incapable of discovering, need not trouble us; let us attend faithfully to our own task, without whose

fullfillment, all that our investigations could teach us would be but an unintelligible collection of almost worthless curiosities. Observation is but an introduction to science; facts give us information but not knowledge. It only becomes science, when logic and imagination are brought to it, and when the facts have passed through the loom of the artisan of thoughts, and the non-essential have been sorted out, the homogeneous have been woven into a higher unity, out of which the matchless gift of foresight, that we call imagination, reaches the new and the unknown, and seeks in hypotheses and theories to trace out the path for the seeker of facts. It is necessary therefore to constantly distinguish between scientific handicraft and scientific speculation. Both are honorable. Many would maintain that only the handicraft brings forth the pure gold; this is, however, not correct, the philosopher also is needed.

He shows the craftsman the road; but must go only where the latter can follow. It was a long while before it was realized that science could produce its best result only when these two worked in coöperation. Two generations ago philosophy presumed to usurp the whole field of the science of life, but its little ship was soon

wrecked; a generation ago the empiricists grasped the rudder, and ran upon the sands of a purely mechanical comprehension of life; now it appears as if each had learned the value of the other and was satisfied to work in his own sphere. This can not fail to bring good to science.

We, at least, will follow this method, and will now give the floor to the philosopher, and listen to his estimate of the facts concerning the sense-life of plants.

If he is a true philosopher he will, moreover, warn us just how far to give him our confidence, since his sphere is that of conjecture. He informs us at once that all these marvelous facts that we have learned concerning the rootlet nerve, the phenomena of light attraction, and the movements of the Mimosa and the sun-dew certainly indicates a definite communication within the plants, that theoretically must lead to some sort of a nervous system.

The rootlet tip that turns with every touch, does not bend where it is touched, but a little behind that point. The excitation of the touch must be conveyed further. In the same way the plant does not react at the point where light and gravity directly affect it, but only in definite or-

gans adapted to that purpose. The grain that has been beaten to earth by the tempest raises itself again erect, as every farmer knows, within a few days. But if we notice closely it is only at the leaf-joint, in which the new growth is so affected by gravity as to cause the required upward bending. How is this possible if the effect of gravity is not transmitted. In the Mimosa we can even follow the effect of the exciting touch with the eye as it moves from one leaf and twig to the other. And the sun-dew shows us what it is that moves, a spectacle that has no equivalent in all nature. The sensitive hairs of the *Drosera,* which are already familiar to us have a purple spot like a pin-head; when this is touched we see a dark red point appear at the place touched, which moves upward along the stem. One after another these red spots appear, and everywhere that these fateful points are seen, the hair bends. The transmission of the excitation is clearly visible. By the use of a moderately strong magnifying glass it is easy to see that they are accompanied by a remarkable drawing together of the cell contents. In all the cells of these hairs there is a purple fluid, out of which dark purple grains are exuded under the excitation of touch.

Consequently there can be no further doubt that excitation is transmitted in the plants just as in the human body. With us the nerves serve for this purpose. So in all earnestness we are confronted with the question of whether the plants possess nerves.

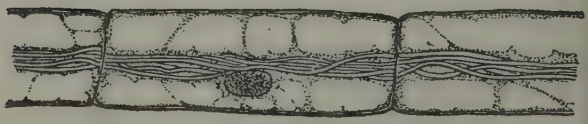
There has been much study of this idea in recent times, and there is an increasing tendency to answer the question with a qualified Yes. The Yes is still qualified because these "plant nerves" are something quite different from those of animals, since they must be adapted to the peculiar life of plant bodies.

The beginnings of their discovery extend back twenty years and yet we are not clear concerning them. So slowly moves the machinery of science; but in my opinion it is in just this ponderousness that a good part of its security rests. In 1884 the following remarkable facts were discovered: when any growing portion of a plant, be it the leaf of an oak or a moss, is wounded, cut, burnt or torn, a peculiar growth appears around the wound. I have already mentioned this fact, but must describe it somewhat more closely. In all the surrounding cells the contents shrink up as if in pain, and there flow from the side nearest the wound, those little grains

whose real significance is still unknown but which are called nucleii. These movements, however, proceed from cell to cell, becoming constantly weaker with the widening circle, and entirely disappear at a distance of about a centimeter from the wound. After a few days all the tiny Amœbæ crawl back to their accustomed place in the cells, and the agitation of the plant is exhausted. There is here a suggestion of " feeling," which a Bohemian scholar, Němec, very skillfully used to discover a trace of the paths of this transmission. The nervous system of the plant was first discovered in the root of the domestic onion, and soon in many other of Flora's children, including the hyacinth, the water lily, the ferns, and later was confirmed in millet, gourds, peas, and potatoes.

Just as far as the " wound irritation " extended, just so far there was found to extend in the cells of all plants, running lengthwise of the cells, fine fibres, looking something like those in our illustration. The " wound irritation " was transmitted only in their course, which speaks much in favor of our supposition that they function as nerves. Indeed in many plants, as for example, in the beautiful tansy, so thoroughly hated by the old apothecaries, and in many water plants, there

are certain definite rows of cells in which these fine threads are laid and it is just along these rows that the cells can best telegraph to each other such terrible news as "our great provider and father, the root tip, is wounded." The keen investigations of the scientists have brought still other proofs. All transmission of irritation ceases when the temperature suddenly drops from 20° to 8° C. The telephone line is interrupted, the fibres untie, the connection is broken.



Cells with irritation carrying fibres from the root-tip of an onion (strongly magnified).

But the moment that the line is repaired the function begins again. That is certainly a marvelous apparatus, in which the line repairs itself, but life creates just such marvels, and therefore it is the most interesting thing on earth.

But here our knowledge has once more reached an end. We can only continue it with speculations. So we must conclude that these nerves

are not the exclusive, but simply a better means of transmission, for even without them there is a continuation of influences. Furthermore there must be some sort of a secret connection between them and the cell nucleus, for they are almost always connected with it. To what end? That to be sure, we do not know. Finally, it is just here better than anywhere else, that the peculiar character of plant life is exposed. Many are convinced that the plants form a sort of experimental field of nature, in which various new ideas are tried, in order to discover the useful results which are afterwards applied in animal and human bodies. The nervous system of the plants is therefore only transitory, a provisional arrangement, that affords temporary assistance, and then dissolves itself. This seems reasonable for we find these organs only in the youthful embryonic portions of plants. In the older cells it degenerates. In the moment that it is used, the system of threads is strengthened by the functioning for some thirty minutes, and is the strongest just at the time when the strongest excitation is transmitted. But after a few days the whole complicated machine is dissolved, leaving no trace behind; just as we, after having made a successful experiment, take our improvised ap-

paratus to pieces, in order to use its portions elsewhere. After all, the final result of this experimental telegraph is very imperfect. The plant needs a whole day to send a message seven millimeters. How infinitely modest are the demands of such a creature on the world when this satisfies it. Before Němec had discovered these protoplasmic threads *(fibrillen)* the existence of still another method of transmission of irritation had been demonstrated. It had long ago been discovered that the cells of plants communicate through infinitely fine threads. The walls of these little chambers have tiny peep-holes, through which the residents can touch hands. Accordingly it was thought that it was through these connections that communication was established. It was only an hypothesis, but nevertheless we are still compelled to partially refer to it. But the philosopher, whom we have visited in search of further information does not permit us to tarry long with this thought; it only forces him to draw the logical conclusion from the fact of sense organs and stimulus transmission, which is: Wherever there are life activities and stimulus there must be apparatus to receive and transmit them. Of what use is such an apparatus, and such transmission if there is not something

that can receive the experience and utilize its results? Such a reception is called sensation but the utilization of sensations implies something — that we have been accustomed to designate by that puzzling word *soul. (Seelen.)*

Perception and souls in plants! To have spoken of such things thirty years ago would have at once deprived us of the right to be considered scientific botanists, and even now many botanists, will not agree with us. We must accumulate an endless store of facts before mankind will believe that a "Soul" is not something peculiar to man. Thousands upon thousands of examples must be piled up, before humanity, that for thousands of years has been taught differently, can be convinced that fishes, beetles, crabs, worms, polyps, medusæ, sponges and infusoria, though growing ever simpler and more transparent in matter and structure, nevertheless maintain throughout the whole series a brain that continues to shrink, and is finally dissolved into single nerve cells, until the last nerve-fibre disappears in the sponge, which is but a colony of Amœbæ, and that even these Amœbæ, the simplest of animals, like a minute drop of almost clear water, are still capable of moving, eating and multiplying, and contain within themselves

all the riddles of perception, and a trace of the will as the last remnant of the "Soul."

But what we are compelled to grant to the Amœba and the Monad, can according to the same principles, not be denied to the living fungus, and just as little to the whole great host of sprawling, swiftly shooting, green and transparent plantlets that populate with their multitudes ocean, rivers and ponds, the study of which has been the life-long task of so many naturalists. From this it also follows that many of the things that are essential to one plant, may be wholly lacking in another, at least of the more complicated higher ones, and so we come, by the way of zoölogy, to one of the principal recognitions of the possibility of psychic activity in plants. . . . How much more, however, have we seen this in our experience with the plants themselves.

But the psychology, which has led us there, has always been a battle ground of fantasy, and in no science are there so many tombs of beautiful ideas. There is a tendency to see a reasoning human being in everything, and to consider all actions outside ourselves from our point of view; this error of anthropomorphism, from which we can never wholly escape, because it is an inevitable part of our mental make-up to think

the world through our own heads — this has played us many a sorry trick, especially in psychology. It has gone so far that poetry is little more than a systematic anthropomorphism, and every beautiful comparison is handicapped with the weight of this mental error. Therefore we should not laugh too much at the honest old physiologists of our grandfather's time, who in such a simple-hearted way wrote such frightfully long treatises on the happiness of the flowers, their wishes, their weariness and their conversation. Who knows how naïve is our psychology? At that time the philosopher unhesitatingly granted the plants a soul. Indeed one of the leading spokesmen of these "speculators" said with a certain logic, that the soul implied immortality, and wrote a beautiful work on the immortality of plants. To be sure it was this same natural philosopher, who, with a most delightful boldness, which reminds one of the Middle Ages, asserted that their science was able to prove how something could come from nothing.

But was there not in all these exaggerations a more nearly correct conception of the real essence of nature than the equally dead, but "exact," and therefore orthodox, schematism of the *veri botanici?* It appears as if no man's thoughts can

be wholly false — certainly also not wholly correct. Mankind soon gropes back to the middle way, only to go off on the other side. The philosopher Fechner, on whose work so much stress is laid at present, because we are just now eagerly springing from the road along which we have just come, is certainly much more insipid than his teachers Martius and Oken. His book on the soul-life of plants is worth reading, but nevertheless is confusing,— a sort of conflict between an ingenious insight and an ingenious imagination. If he means that the plants resemble, in their general features, animals and men, so that we can draw no fundamental distinction in their life processes, then we applaud in agreement; immediately afterwards, however, he would tell us that the gay dress of the flowers serves to entertain them, that their perfume is their speech and that their blossoms have memory and foreboding.

Then it is much better to close the book and go out once more to the great source of wisdom, nature itself.

I think that when we consider what has been said so far, we can no longer doubt that the plants must possess the beginnings of sensation since every reaction to an impulse, every blow of the stamens, every curling of the tentacles, self-erec-

tion under the influence of light and gravity, the taste, search and flight of the spermatozoa,— all this would be impossible if the plants did not perceive an impulse and its cessation. But it is noteworthy, that so great is the influence of the Linnaean dogma of the non-feeling plants, that many investigators would rather invent outlandish theories, than unreservedly accept the fact of sensation. They prefer to say that all these responses of the plants are such only in the sense that a finger pressure upon the lever of a machine sets this in motion, because the power was already stored up, and needed only to be released. Is not that, however, only a skillful evasion of the idea of sensation, because it is just this lever which manipulates the physical powers? All of my involuntary movements are released by sensations. Similar events take place by the thousands in plant life, furnishing us the best possible proof that sensation exists there also. That cutting, crushing and burning is perceptible to the Mimosa, and that other organs than those immediately affected respond, is the best evidence of this.

The Mimosa is such a delicate thing that it is generally kept under glass. If it is suddenly uncovered on a cool day, the leaves tremble as if

they were shivering in a cold shower, and show us by this sense of temperature, that they have *felt* the cold. That we are not here dealing simply with a mechanical result, such as the heating of iron by pounding, is shown by the strange behaviour of this plant when we take it on a journey. In a smoothly rolling first class car, its leaves sink and rise only at long intervals, when some unavoidable jar is encountered. But if we take it into the roughly jolting third class car, and thereby subject its leaves to continuous movements, and then return it to the first class it will finally come to rest. It has become *accustomed* to the milder irritation, something that a purely " mechanical " power could not do.

The thought must inevitably arise that if plants have sensation, then they must *feel pain.* What a romantic perspective this opens! How much pain and sorrow we must daily inflict upon nature! The peaceful clearing in the forest would become a martyr's chamber, and every nosegay cost the garden a hundred painful wounds. Now we can not definitely answer this question, for it depends upon something else; on the possession of *consciousness.* Where there is no consciousness, there is no pain — where there is no memory, there can be no consciousness. This

rule holds good for practically the entire field of animal psychology. We are unable to find any sign of consciousness in the lower animals — how much less then may we expect it in the plants. On the other hand it must be admitted that the existence of sensation is peculiarly identified with the idea of painful feeling; all the more so, in that it is indicated by certain signs as "pain reactions." We might refer to the irritation from wounds, but this is already familiar to my readers. I will therefore offer another illustration. As Darwin was the first to investigate, an injury to the sensitive rootlet end causes regularly convulsive curlings of the whole rootlet. So it is not alone the worm that turns when it is trodden upon, but the rootlets also, if severely injured. Even more, just as in man and animal, so it is possible also with the plants to destroy sensation by an excess of excitation, until they are stunned and stupefied. The injured root is for a long time indifferent to gravity and light, just as a man suffering from a jumping toothache becomes indifferent to minor injuries. Chloroform, too, causes a cessation of all reaction to irritation, as does also alcohol.

All this causes the scale to incline heavily towards the view that trees and flowers share in

the many pains that life brings to all living creatures. It even appears to me that it is largely the complete novelty and strangeness of the idea that prevents our scholars from openly endorsing it.

Moreover there are many among them who unhesitatingly admit much more of a "soul character" than this to the plants. One of the leaders of the new plant biology, Prof. Kerner, speaks boldly of the instincts of plants, and supports his position with weighty arguments. He refers to the well-known division of labor in plant life, that is not conceivable without mutual exchange and a general coherent plan. The physical forces are not all utilized by the whole plant, but some by one organ, some by another; all are adapted to the immediate necessities, so that, for instance, the same light rays that attract the leaves, repel the roots.

Indeed, every little portion of the plant carries on its own particular work, in the manner that will best help the whole State. In human life we call such systematization, division of labor, and it is not conceivable to a human brain without some central direction of the whole. We must, therefore grant the same thing to the plant individual, and we may call it *Instinct* or *Soul* as

we wish. This central director occupies itself with those unconscious purposefully planned activities so marvelous to us, and which are simply inexplicable without the acceptance of some such hypothesis. So far Kerner. What facts has he in mind when he speaks in this manner? He knew but a small portion of the facts, that since his death have first been known and given their proper weight.

Every hour that we devote to this lovable observation of nature shows us new examples of this characteristic. We already know a few of these. The tentacles of the sun-dew plant, that grasp after a fly, know how to reach their prey with infallible certainty. At the very first movement they inevitably grasp in the exact direction where their prey is to be found. Or let us observe for a moment the water-plants, that are not rooted to the bottom, but swim freely about with their roots reaching out of the water seeking for nourishment. Their thousand-fold branches and inter-woven rootlets send out a thick hairy net tangle around them. And how marvelous! the roots are so arranged within this impenetrable felt, which they form, that they do not touch each other. Is it an Instinct which tells the roots to avoid one another?

We must always refer back to the plant roots when we wish to illustrate some incomprehensible thing in plant life. We already know what a wealth of purposeful acts the dark earth conceals, but all this is exceeded by the roots that live in the air. The mistletoe, sacred to our fore-fathers, as the symbol of an incomprehensible life, that springs into existence and blossoms in the dead cold of winter,— sinks its roots, to be sure, into the tree that sustains it, but these do not obey the great laws that rule all other roots, to dig constantly downward; they only grow where they are able to seize hold and suck, and whenever it is necessary they will grow heavenwards. It seems as if it were not physical laws that governed the plants, but as if life applied the blind forces of nature to her own purposes. *Suprema lex,* the welfare of life. Consider well what that means. Otherwise, what power is it that drives the germ of the parisitic orchids, broom-rape and clover-dodder, to seek the particular growth from which they are fitted to obtain their life? It must be a similar force to that which animates the animals, for they act alike. The hair worm *(Gordius)* a yard-long, hair-like worm, the thoughtless drinking of which from dirty water has made many

persons very sick, is an example of this. It lays its eggs in the water. The embryo which crawls out wanders at once into the larva of a gnat or ephemera until it is swallowed. It derives no immediate advantage from this first act, since it remains quiescent in the larva, undigested and apparently dead, until this has been eaten by a water beetle. Only in the latter does its development proceed. What is it then that leads the worm to place itself in the larva of the gnat? The same mysterious instinct that leads the germ of the broom-rape to search out the roots of a shrub.

There is much more in growing things than the mere capacity to respond to irritation. The theory no longer satisfies, that they are only skillfully built automatons, containing all sorts of contrivances, with a certain number of capacities, which are held back until a definite button is pressed, whereupon the automaton claps and shakes for a time until its storedup strength is used and the clock work runs down. No, these living automatons are something as mysterious as any fantastic creation of romance.

Their functions are closely limited, but they have an independent life. I have often thought that the peculiar riddle of life consisted in just

this,— how an apparently all powerful creativeness can be united to a scheme of physical forces. Perhaps the wisdom of Empedocles offers the true solution, and there is an unconfined spirit in everything, which can only gradually free itself from the bonds of matter — most of all in us, less in the animals, and still less in the plants, and becoming in its lowest manifestation only perceptible, as an eternal causal relation, in dead matter itself. This poetical figure is perhaps the best description of the reality.

The plants possess a capacity to utilize their environment, which is developed according to the given circumstances. This is especially evident in an example, that seems to me to be the most interesting known to science.

In sandy places, and dry meadows, still more frequently on the steppes of our eastern borders, there is to be found an irritating thistle-like growth about as high as a man. It is called the teasel *(Dipsacus laciniatus)*. The people of the steppes, with their closer knowledge of nature, call it the falcon fountain, because they have correctly observed that this thistle constitutes a sort of fountain for the feathered population of the steppes.

Every pair of the deeply serrated, prickly

leaves grow together at the base and form a little cup, which the rain fills, and the morning dew retains for a long time. It has been thought that this was of use to the plant by preparing a watery grave for useless, plundering snails and ants, and thus protecting the blossoms from

The Teasal (*Dipsacus*), with its water-pitchers from which the plant sucks water, and also devours the insects that may be drowned in it.

them. While this may be so, yet there is a still more interesting feature. The plant of its own initiative makes use of this reservoir. We may turn and twist the fact as we will, but we can not change its existence. None of the other members of the teasel family, and none of the thistles have anything similar. This one alone develops suction cells on the bottom of its water cup, which can absorb the water when needed, and so assist the plant in maintaining an otherwise precarious existence upon the dry steppe. But this is not all. Such a little fountain will not remain unvisited. Thirsty gnats, and industrious ants, use it frequently, and very many of them slip on the smooth rim and miserably drown. The water macerates their tender little bodies, and a most marvelous happening follows. The plant sends out countless tiny little hairs of protoplasm to the pleasant meal of corpses, which serves to help out the penurious gifts of the sandy soil. It is the old story of the robber caves of the broom-rape with this difference, that what was there a permanent purposeful contrivance, is in the thistle only an occasional expedient. But that is just what determines it to be an act of instinct.

In spite of all this we are still a long way from

the proof of a soul — and still further from any decision concerning the existence of that soul content, consciousness. To be sure one of the master-minds of the new botany, Prof. Nägeli, has unhesitatingly ascribed consciousness to the plants, but he has used the word in this relation, in very much reduced meaning, inasmuch as he hypothetically ascribes a mind to every molecule of albumen. The "Haeckelism" of the present day also, has arrived at a point where it attributes a soul to matter. Such positions, however, are not results, but suppositions, arbitrary assumptions in order thereby to attain the incomprehensible. The truth is that we know nothing about whether the plants have consciousness or not. If we are optimistic, we can at least say it is not impossible.

Are we to conclude, then it may be objected to me, that below instinct there is still another, even if a lower form of soul activity? Here the botanist can no longer help us, if he is not familiar with the new psychology. I must emphasize once more the fact, that it no longer suffices to be simply a botanist, if one wishes to fathom the "existence" of nature. There are tremendous tasks for the nature student of today. The endless division and immeasurable extension of

knowledge would appear to make impossible any future universal historian and encyclopedist such as was Alexander von Humboldt, since from now on to be an encyclopedist means to be able to utilize for each immediate purpose all the advances of physics, chemistry and still more of the whole field of biology. Indeed it appears to me that the preëminence of the really great student of nature at the present time, over those of previous ages, consists in just that universal view of the whole which is granted to him, and in his clear recognition of the great inter-relation and unity of the physical and biological sciences in one great natural process.

So we also, now that we have followed the analysis of the sense life of plants to where we begin to recognize signs of a primitive instinct, must leave botany, to pursue our search in the field of comparative psychology, if we are to meet the objection given above.

Modern psychology, however, makes short work of all dreams about instinct as a form of soul activity. It refers us to the countless experiments with animals, which, as yet have no nervous system, or in whom it has been artificially destroyed, but who are still able to show essentially all the phenomena, which heretofore

have been held to indicate the existence of a soul. This simple form of soul activity, which operates wholly without consciousness, is called reflex, a word which everyone will understand when he is told that the involuntary closing of the eyelids when a sudden violent sound is heard, is such a reflex. We can not control it; it falls entirely outside the sphere of our will, and happens before the consciousness is aware of it.

These reflexes characterize the beginning of all life processes. The first answer to any impulse is always a reflex. And so the manifold answers that the plants give — their inclination towards the light, the bending of the roots away from injury, are essentially reflexes, and as such have no need of consciousness, soul or instinct. The capacity for reflexes is possessed by all living substance. The cause of these reflexes is simply the universal irritability of this living matter, the capacity for tropism, for irritability. Where such reflexes unite, coöperate, combine in a system, the resulting higher life activity is called an *instinct*. This origin of the instinct teaches us that it also is no proof of a soul, that its existence can still always be explained by the universal characteristics of living matter. It is not a psychic attribute. The soul begins only

with consciousness, and we have no signs of this before we reach the higher mammals — and to be absolutely correct — each one only knows it for himself. The students of life will never find an objective "Soul," but only nerve and brain activity — and these are always united to nerves, ganglion cells and brain. For the exact student of nature therefore, there exists no "science of the soul," but only a "science of nerve life."

So much for the ruling school of neuropsychology. Perhaps my readers are satisfied with this view. As for myself I am not quite satisfied with it.

It is doubtless absolutely correct that the final conclusion from analogy that our ego is made up of the same motive forces in the phenomena as those out of which this consciousness is composed is not wholly satisfactory to the logical mind. Since Kant has worked out this idea, it is hard not to see it.

It is also a grand idea to reduce the acts of all living creatures to a single attribute: the irritability of living substance.

But it seems to me that the words of Goethe apply here: "What man knows, he can not use." Of what real use is this knowledge of a

universal all-explaining irritability, when this irritability is itself inexplicable?

It is only playing with words when one inexplicable is simply replaced by another.

In this case the true scientific spirit grants unreservedly that the reflex actions of plants are identical with those of animals, but what they actually are we do not know. Therefore we must confine ourselves to describing these reflexes as minutely as possible in order to reduce the field of the unknown, and thus concentrate upon the central point of the question. Even then no one knows how it is that the characteristic of all these phenomena is purposefulness. Not teleology in the old naïve sense of the words, which implied that all nature existed only with reference to mankind, and accordingly was there only to satisfy our purposes, but an indescribable purposefulness of each creature in relation to itself.

All tropisms are in the service of life-activities. The nyctitropism of blossoms and buds accomplished a protection from dew and cold; that inexplicable folding together of the germinal leaves that is to be observed at night with clover, gourds, tomato plants, or sunflowers, is of great use to the germinating buds that are between

them, and would otherwise be frozen. The circling of sprouts and tendrils is in the service of a higher purpose, for without this circular movement the hop-vine could not climb, nor the grapes cling. Without the host of tropisms they possess it would be impossible for the roots to maintain the whole plant. Without heliotropism every growing thing would be unable to utilize the benefits of the light. Even those tropisms that appear senseless to us, assist in this strange "care" for the welfare of the individual. Geoptropism, for example, does not simply care for the maintenance of an upright position, but also for protection against extreme drying out of the soil. Every tree and bush and every vegetable that uses much water, because of its upright position, shades, just at the most parching portion of the day, the bit of earth in which its roots are digging for moisture.

The final proof of this position is furnished by the fact that the form of the reaction corresponds to the necessities — indeed it is discontinued when the welfare of the individual demands it. Darwin has already observed that too great drouth many times affects the sleep movement and night sensitiveness and that the leaves no longer close up from this cause. But why? We

know no answer, further than the excuse that Darwin used: this is done in order to stop evaporation. This is the result that is actually attained, but do we dare thus to reverse the course of natural events and explain a cause by its effect? Heliotropism also adjusts itself to necessities. "If, as a consequence of changed habits of life it becomes injurious to a plant, then, as in the climbing and insect-eating plants, the sensitiveness will be quickly abolished." Who made this incredible statement? No other than the great Darwin in his book on "The Power of Movement in Plants." And really, if we are not to give up all explanation, we can scarcely give any other, although in so doing we make the terrible statement that in this case the motive power is its own necessity. Darwin has made a significant experiment in order to clear up this question. A young plant was brought into a darkened portion of a room, whereby the greatest possible nyctitropism was aroused. The cotyledons raised themselves up and folded together over the tender germs that lay between them. Another plantlet was placed in bright sunshine, and the cotyledons opened as widely as possible. Both pots were then simultaneously placed in the middle of a moderately light room,

and what was the result? The open cotyledons closed at once, and the closed ones opened. This is an experiment that may mean little to the ignorant, but to the scholar, it shows the sovereign domination of life in a manner that might well cause the observer to start back as in the presence of an expression of some great, vital cosmic force.

Whoever dives deep into nature, knows only too well, how the fairyland of our childhood's fancy is made reality all about us. For no imagination could have conceived all the wonderful things that the student of nature discovers. And many times it needs no complicated apparatus to see these things. The marvel that is always before our eyes is well concealed. For instance there are the tendrils of the so-called wild grape *(Vitis inconstans)*. Every child knows it. But how many have ever noticed the remarkable sucker-footed leaf by means of which it climbs up an iron trellis? The tendril ends in a little handle, on whose extremity there is a drop of clear transparent cement. This holds so firmly that the tendril may be torn in two before it can be loosened. Where did this come from, and why was it only formed when the plant had need of it? Oh, if we only knew! There are also

tendrils with insect-like feet, having sharp claws on the end that hang fast to whatever they grasp. To be sure Darwinism comes to our assistance at this point with its selection hypothesis, and teaches us that the essential is here just because the unessential is constantly being eliminated

The wild Japanese grape, that attaches itself to the smooth wall with its "tree-toad feet."

from the ranks of the living, while the "accidentally" appearing little hook on the tip of the tendril, because of its usefulness to the plant race, is maintained by just this advantage.

Good, this may well be, although it is always misleading and dangerous to appeal to "accident." But it fails to account for the creation step by step of the drop of cement. For if we agree to be satisfied with the explanation that irritation through contact originated this gummy formation, this still fails to clear up the heart of the whole matter,— why, in just this one case, a function appeared of which the whole plant could have made use.

This purposefulness of living beings presents itself to us again and again, in hundreds of strange disguises, as an eternal law apparently breaking through the disorder of all other natural events, as the true crux of all future scientific investigations; indeed I do not hesitate to say that it is the great central problem insoluble to us, indeed scarcely conceived, whose solution we shall leave to our children.

Here, all our science and our learning disappear in fog. In these final questions as to the consciousness of living matter, of soul and the springs of life, and the true reasons for purpose-

fulness, our wisdom opens up no solution but only a line of thought which can end only in a quarrel between those who pursue it.

This time it is really no battle, but only a quarrel to conceal ignorance. But man has not wandered in vain on this dim tiresome, treacherous path. Even if all our hopes are not realized, we have brought away a mighty knowledge that reaches down into the very depths of all being: *the certainty that the life of plants is one with that of animals, and with that of ourselves.* What grander lesson could the speechless plants give than that which they have taught us: *that their sense life is a primitive form, the beginning of the human mind!*

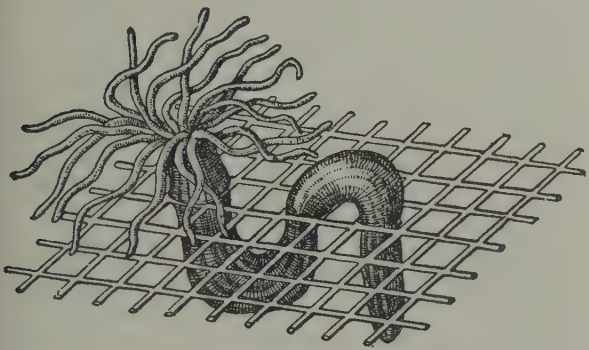
The latest discovery in the field of vegetable physiological psychology is that all its discoveries are not new. The plants are only different in form from the animals, not different "beings." All that we know of their tropisms, reflexes, instincts, we find to be characteristic properties of animal organisms also, and therewith falls the last of the artificial partitions which were once erected in the kingdom of nature as a necessity for systematic arrangement, and then because of that strange fetichism which man so willingly

gives to his own creations, came to be looked upon as divisions of nature itself

It is not difficult to bring proofs of this assertion. Every nature lover who possesses a sea-water aquarium can easily test this, for he will certainly have one or more of the beautiful sea anemones. It was not without reason, that for centuries they were firmly held to be plants, and that such a scientist as Reaumur maintained the name in the face of all ridicule, and only subsided when the Paris Academy of Science testified to their animal character. They are so much like plants that we can now use them as a proof of the identity of all life.

These anemones follow the effects of light and gravity as closely as a leafy twig, and therefore they all move toward the illuminated side of the aquarium, and place themselves perpendicular to it. A joke may be played upon this clumsy plant-animal, by placing it upon a grating through which it can easily slip, when its geotropism will force it to take the position shown in the cut. The grating being repeatedly turned over, the free rear end of the anemone seeks constantly to attain its perpendicular position, and in so doing shows by the remarkable bending how strongly it reacts to gravity. With equal

twists and bends its tentacle adorned head seeks the light, to which this animal is as completely adjusted as the leaves of the plants.



The sea-anemone (*Cerianthus*), compelled to take the above unnatural position in attempting to follow the attraction of gravity.

The heliotropism of animals is not confined to the depths of the sea. Wherever the life substance takes on the movable form of an animal body, we find an inbred attraction for light and so it is that the lowest animals have a light sense in their skins such as we have seen exists in the tips of the grass leaves.

The moth flying into the light is nothing but an example of heliotropism; when the earth-

worm shyly flees from the light of day, it is in obedience to the same force that causes the root to turn from the light. The same laws rule both, therefore the same peculiarities will be found in the animals as in the plants. Moths and butterflies that sleep by day and fly out only with the coming of twilight, do not change their life customs when they are kept for a day in a dark room. At the accustomed hour they begin their flight. So with many plants, they take their sleeping position without regard to whether it corresponds to the conditions in which they are. But this only happens once or twice. Then the force of habit is broken, and butterflies and plants alike adjust themselves to the changed circumstances. Life thus triumphs once more over the tasks that man has set for its capacities.

That the response to changes from day to night in animals is not dependent upon the sense-organs and their assistants, the nerve-cells, is shown by the fact that the eyeless maggot of the common fly will crawl towards the light as anxiously as the night-flying moth.

These considerations inevitably suggest the thought, that perhaps the true explanation of why darkness makes us sleepy, even in the daytime, why the stranger finds it difficult to sleep in the

bright light of the northern summer nights, is also to be found in heliotropism. Is there some remnant of the plant character still in us? Do our eyes still conceal something they learned of the green plant discs? Just as the leaves turn toward the light, so in the human eye, touched by a sun-beam, the coloring stuff and the delicate rods of the retina are pushed toward the light and then move back into darkness.

The tendril that clings so firmly to the chosen twig, has its counterpart also in the animal world. It has only been a few years since this fact has been recognized. The difference is only that the same characteristic which in plants is called *contractability,* is in animals called *stereotropism.*

It is stereotropism, and not aversion to light or fear, that causes the beetle to creep into a crack, or the ear-wig to bore in like an auger, or the cock-roach that has been frightened out into the open to seek so quickly a hole in the wall. So at least the new psychology declares, with which, however, I am not wholly agreed. But my objections do not apply to the essentials of the matter we are now discussing, since I am ready to agree that the action of the arms of the polyp in changing to its surroundings can be in no way different from the curling of the tendril around a

stick. Both depend upon the irritation caused by a fixed body.

But with this our comparison must end. Certainly it is not exhaustive, but only sufficient to convince us that in its essentials, *the sense-life of animals is only a higher developed stage of that of plants.* The lowest animal, in this sense, is wholly comparable with the highest plants. The difference, which at the first glance causes the animals to appear as living and the plants as lifeless, is due only to the *tempo* of events. All reaction movements are quicker in animals. The movements of flowers have been photographed and transferred to a cinematograph, and then reproduced in the *tempo* of animal movements. They gave the fantastic picture of some fabulous being in tremendous agitation. But in spite of the slowing up, the life functioning is the same, just as the nerves of animals are essentially identical with the simple temporary instruments of the vegetable nervous systems. A moment's thought will make this plain. The movements of the plants do not require this great apparatus of muscles and nerves. The animal, that must seek its food and maintenance over a wide extent of territory, must run and climb in breathless haste, if it is not to starve; its whole

body must accordingly be adjusted for rapid action. It requires sharp and fully-developed senses; it must have a skillfully constructed internal telephone, and a definite central control of its entire apparatus. The plants on the other hand, which are, so to speak, stuck into their nourishment, can usually dispense with movement, they need know little of the happenings around them. Air and rain come to them, therefore they need not worry about them. They have nothing to communicate, therefore they can exist without any regular nervous system, without a brain, and with only primitive sense organs. But their powers are only sleeping. How often have we seen this. The moment that movement is needed they can act as quickly as the most nimble animal. When they must observe, they notice all that is necessary. They are no stepchildren of nature; they are as completely adapted to their life as is the animal to its life. When an animal is no longer compelled to trouble about its food, the clam and the polyp show that it becomes simply an organless sack, like many parasitic animals.

There is therefore no "animation," no sudden introduction of a "soul" by nature, but we are all united in the same encircling unity, whose in-

ternal yearnings and unconscious comprehensions form the germ of all nature religions, and give them their real sanction and their peculiar value.

A measureless perspective stretches away when we consider this inner, secret connection, through which nature maintains the circle of events, and seeks to utilize to the best all relations of all beings. There is no truer devotion than that awe which comes over us when we have even partially comprehended this puzzling, gigantic, unconquered power of life upon this earth.

As yet we are far from being able to understand and explain its true essence, but the feeling grows ever more definite that life is a special force, standing on an equality with the other forces of nature, which transforms the raw material into something whose final form is unfortunately still concealed from us by the clouds of our own limitations. In this unfortunate condition of uncertainty, the one firm point to which we can cling is the *feeling of complete inner unity with the creative and transforming forces of nature.* To be sure this unity hurls us back, deep under all, to the imperfectness of crude beginnings, and primitive life forms. But at the

same time it raises us to all the possibilities that lie hidden in the limitless creativeness of nature, And through this we may also understand how high and low struggle in our breasts, for it tells us that after all the living world is but mankind in the making, and that we are but a part of all.

A FINAL WORD

The noblest work of a book that aims to extend knowledge is to add to the freedom, enlightenment, and love of beauty in the minds of its readers. It should undoubtedly aim to raise its readers as far above the mass of prejudices concerning the essentials of life as science has been able to raise itself. But that is not the only mission of such a book. I at least dream of the possibility of something more.

Perhaps there may be some, who, attracted by this very hasty glance at the hidden life of field and garden, will desire to penetrate deeper into this puzzling world of silent, yet powerful forces, and with whom that interest may finally deepen into a noble, intellectual, loving relationship, that will raise them, in the hours that they devote to it, high above the everyday life, and bring to our science eager, industrious friends and co-workers.

Science and culture certainly need such. There are many nature lovers, but still far from enough

to drive back all the powerful enemies of progress. It is just these who have a great and fruitful work to do. They must not only form the bulwark of progress, but because of their independence, they must be looked to to defend science itself from narrow dogmatic scholasticism.

They are the best and truest friends of that new cultural ideal, who slowly but surely prepare the way to the transformation of our still mediæval world, and create a proper atmosphere for the full appreciation of natural laws.

While they are themselves gaining a higher position, they draw the world along with them. This is true because it is only when surrounded by many who have the same thoughts that the great natural scientist can arise. Great minds can only develop where they are understood. This demand always brings its own supply. This statement holds true, not alone in political economy, but in intellectual economy as well. The army of dilettanti and nature-lovers support the staff of the investigator and thinker — from whom in turn come the great leaders of humanity, the world-emancipating minds, of which perhaps but one appears in a century . . . and who, when he does appear, cannot fulfil his real

life work, that is to last for centuries, unless he can utilize the forces and intelligence of thousands in his service.

In order that these earnest-minded ones may not lay my book down unsatisfied, I dare not conclude it without indicating the sources from which the wider knowledge flows, of which I have given but a slight sketch here.

The most important work on the sense life of plants is W. Pfeffer's "Physiology of Plants."

Further material on the life activities of plants will be found in R. Francé, "Die Weiterentwicklung des Darwinismus."

On the sense organs of plants, see G. Haberlandt, "Sinnesorgane im Pflanzenreich zur Perzeption Mechanischer Reize."

On the transmitting of sensation in plants, see G. Haberlandt, "Das reizleitende Gewebe der Sinnpflanze," and B. Němec, "Die Reizleitung und die reizleitenden Structuren bei der Pflanzen."

On the "Soul-Life" of Plants, there is something of historical value in Fechner's "Nanna, oder über das Seelenleben der Pflanzen."

On the identity between animals and plants in respect to their response to heliotropism, see Jacques Loeb, "Studies in General Physiology"

and "Comparative Physiology of the Brain and Comparative Psychology."

See also Arthur and MacDougal's "Living Plants and Their Properties," and especially Darwin's "Power of Movement in Plants" and "Insectivorous Plants."

(In preparing the above bibliography, the works indicated by the author have been given in their English translations wherever such existed, and a few works have been added by the translator, including those more easily accessible to the English reader.—*Trans.*)

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